Indian Institute of Technology Kanpur

COURSES OF STUDY

2021

Indian Institute of Technology Kanpur

KANPUR-208016**AEROSPACE ENGINEERING**

AEROSPACE ENGINEERING

B.TECH.								Template No. AE-1
	SEMESTER							
	1st	2nd	3rd	4th	5th	6th	7th	8th
C	MTH101A [11]	MTH102A [11]	ESC201A [14]/ HSS-2 (Level-1) [11]	HSS-2 (Level-1) [11]/ ESC201A [14]	AE311A [09]	AE341A [11]	AE441A [05]	AE462A [04]
O	PHY102A [11]/ PHY103A [11]	PHY103A [11]/ PHY102A [11]	ESO/SO-1 ESO204A [11]	ESO/SO -3 ESO201A [11]	AE321A [09]	AE351A [05]	AE451A [05]	AE421A [03]
U	PHY101A [03]/ CHM101A [03]	CHM101A [03]/ PHY101A [03]	ESO/SO-2 MSO202a[06] AND MSO203b [06]	ESO/SO-4 ESO202A [11]	AE331A [09]	AE361A [03]	AE461A [07]	HSS-5 (Level-2) [09] OE-4 [09]
R S	TA101A [09] + LIF101A [06]/ ESC101A [14]	ESC101A [14]/ TA101A [09] + LIF101A [06]	AE201A [05]	TA202A [06]/ TA201A [06]	HSS-3 (Level-2) [09]	AE322A [09]	AE401A [02]	OE-5 [09] DE-3 [09]
E	ENG112A/HSS-1 (Level-1) [11]	CHM102A [08]	TA201A [06]/ TA202A [06]	AE211A [11]	OE-1 [09]	HSS-4 (Level-2) [09]	DE-1/ OE-3 [09]	OE-6 / UGP-3 [09] (AE472A)
S	PE101A [03]	PE102A [03]	AE231A [06]/ ESO209A [08]*	AE251A [08]	UGP-1 (04) (AE371A) (Extra Credits)	OE-2 [09]	DE-2 [09]	UGP-4 (Extra Credits) *(May be taken in the summer after 8th semester)*
	-	-	COM200A [05]	-		OE-3/ DE-1 [09]	UGP-2 [09] (AE471A)	
	54	50	56 – 61	58/61	45/49	55	46	52

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	111	Credits
UGP-2	:	09	Credit
**Department Elective (DE)	:	27	Credits
Open Elective (OE)	:	54	Credits
ESO/ SO	:	45	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	419	Credits

Basket-A
AE641A [09]
AE662A [09]
AE673A [09]
AE777A [09]

REMARKS:

1) *AE231A may be replaced by ESO209A. In either case, these credits will be counted as part of the department compulsory credits.
2) **At least 9 credits of DE must be taken from Basket-A.
3) OE credits may include 9 credits of UGP-3.
4) UGP-1 and UGP-4 are optional and do not count towards graduation requirements. UGP-4 may be taken as extra credits by a student in the summer after the 8th semester.
5) 09 credits of UGP-2 and upto 27 credits of OE may be waived from the minimum requirements for students opting for dual degree in AE itself.
6) Upto 36 OE credits may be waived for students opting either for Dual Degree in another department or the Double Major programme.

BT-MT (PG Part – Category – A) *(from the same department)*					Template No. AE-2
C		7th	8th	9th	10th
O		DE PG-1 [09]	DE PG-4 [09]	M.Tech. Thesis [36]	M.Tech. Thesis [36]
U R		DE PG-2 [09]	DE PG-5 [09]	-	-
S		DE PG-3 [09]	DE PG-6 [09]		
E S		27	27	36	36

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION:

PG Component	:	54	Credits
Thesis Component	:	72	Credits

REMARKS:

1) DE PG-1 may be taken instead of UGP-2 in the BT programme.
2) Upto 27 OE credits may be used from the BT minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the BT programme and counted towards PG requirements.
3) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech. part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme EXCEPT for credit waivers detailed above.
4) All courses to be taken with the permission of Supervisor/ DUGC Convener.

BS/BT-MT (Category – B) *(from other departments)*					Template No. AE-3
	UG Pre-Requisites	PG Component			
C	ESO201A [11]	7th	8th	9th	10th
O U	ESO202A [11]	AE601A [09]	DE PG-3 [09]	M.Tech. Thesis [36]	M.Tech. Thesis [36]
R	ESO204A [11]	DE PG-1 [09]	DE PG-4 [09]	DE PG-6 [09]	-
S	ESO209A [08]	DE PG-2 [09]	DE PG-5 [09]	-	
E S	41	27	27	45	36

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION:

PG Component : 63 Credits
Thesis Component : 72 Credits

REMARKS:

1) AE offers M.Tech. in four streams: Aerodynamics, Propulsion, Structure, and Flight Mechanics. All DE PG course choices will depend upon the chosen stream.
2) All courses to be taken with the permission of Supervisor/ DUGC Convener.
3) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
4) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the BT/BS-MT dual degree programme. These will be waived from the parent department's BT programme requirements and counted towards PG requirements.

DOUBLE MAJOR		Template No. AE-4
	Odd Semester	Even Semester
	Pre-Requisites	
C	ESO204A [11] / ME231A [09] / CHE211A [09]*	
O	ESO201A [11] / CHE221 [09]*	
	ESO202A [11]	
U		
	33	
R	AE Mandatory Courses	
S	AE231A [06]**	AE211A [11]
	AE311A [09]	AE251A [08]
E	AE321A [09]	AE341A [11]
	AE331A [09]	AE351A [05]
S	AE441A [05]	AE322A [09]
	AE451A [05]	AE462A [04]
	AE461A [07]	-
	50**	48

TOTAL MANDATORY CREDITS FOR SECOND MAJOR IN AEROSPACE ENGINEERING: 98 CREDITS *(**may vary depending on credits of course found equivalent for AE231A)*

REMARKS:

1) *Other equivalent courses for these pre-requisites may be decided in consultation with the AE DUGC.
2) **AE231A may be substituted by ME353 / CE455 / ESO209 or other equivalent course in consultation with the AE DUGC. If an equivalent course is found, its credits will replace the credits for AE231A.
3) Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.

MINOR	Template No.AE-5
Title	AEROSPACE ENGINEEIRNG
C	AE201A [05]
O	Any THREE from:
U	
R	AE211A [11]
S	AE321A [09]
E	AE331A [09]
S	AE650A [09]/AE753A [09]/AE341 [11]
	32-36

Department of AE

Course ID	Course Title	Credits L-T-P-D-[C]	Content
AE100	INTRODUCTION TO PROFESSION	1-0-2-0-0	History of aviation, spaceflight. Aerodynamic shape, generation of forces. Aerodynamics of airfoils. Atmosphere. Performance, stability & control. Structural layout. Power plants. Instruments & navigational aids. Materials. Aircraft systems. Missiles, spaceships, helicopters, airships & hovercrafts. Trips to wind tunnel facilities, flight, structural, propulsion and high -speed aerodynamic laboratories together with demonstrative experiments.
AE201A	INTRODUCTION TO AEROSPACE ENGINEERING	3-0-0-0-5	Fixed wing vehicles: History of Aviation, introduction to fixed wing vehicles, configuration and layout, propulsion, lift generation mechanism, balance of forces and moments, control mechanisms (10 hr)Rotary wing vehicles: History of rotary wing vehicles, configuration and layout, propulsion, lift generation mechanism, balance of forces and moments, control mechanisms (6 hr)Space Vehicles: History, configuration and layout, propulsion, lift generation mechanism, balance of forces and moments, navigation. (4 hr) Demo. Flights in motorized gliders Introduction to Flight: J.D. Anderson, Jr., McGrawHill International Editions.
AE211	AERODYNAMICS I	3-0-0-1-4	Introduction to aerodynamics Atmosphere (ISA) and its stability Continuum hypothesis, dynamic similarity, Aero foil nomenclature, forces and moments Incompressible irrotational flow, Complex potential, Singularities and superposition, Blasius theorem, Method of images Circulation, Robins Magnus effect and Kutta.Joukowski theorem Conformal Mapping and Joukowski airfoil. Kelvin circulation theorem Thin Airfoil theory Helmholtz theorems, Finite wing theory Computational methods; Panel and vortex lattice method slow aspect ratio wings and slender body theory Viscous flows: Introduction to NS equations Prandtl boundary layer equations, Similarity solutions. Integral approach Introduction to transition turbulence. Turbulent boundary layer. **Course Reference**: 1. Aerodynamics for Engineering Students by E.L. Houghton, P.W. Carpenter; 2. Physical Fluid Dynamics by D.J. Tritton, Oxford Science Publication; 3. An Introduction to Fluid Dynamics by G.K. Batchelor, Cambridge University Press; 4. An Introduction to Theoretical and Computational Aerodynamics by JackMoran, Dover.
AE211A	INCOMPRESSIBLE AERODYNAMICS	3-1-0-0-11	Introduction to aerodynamics 1Atmosphere (ISA) and its stability, Continuum hypothesis, dynamic similarity, Aerofoil nomenclature, forces and moments 1Incompressible irrotational flow, Complex potential, Singularities and superposition, Blasius theorem, Method of images; Circulation, Robins Magnus effect and Kutta Joukowski theorem (2 HRS); Conformal Mapping and Joukowski airfoil,

			Kelvins circulation theorem (3 HRS); Thin Airfoil theory (3 HRS); Helmholtz theorems, Finite wing theory (5 HRS); Computational methods; Panel and vortex lattice methods (3 HRS); Low aspect ratio wings and slender body theory (3 HRS); Viscous flows: Introduction to NS equations (2 HRS); Prandtl boundary layer equations, Similarity solutions. Integral approach (4 HRS); Introduction to transition & turbulence. Turbulent boundary layer (4 HRS). **Course Reference**: 1. Aerodynamics for Engineering Students by E.L. Houghton, P.W. Carpenter; Physical; 2. Fluid Dynamics by D.J. Tritton, Oxford Science Publication; 3. An Introduction to Fluid Dynamics by G.K. Batchelor, Cambridge University Press; 4. An Introduction to Theoretical and Computational Aerodynamics by JackMoran, Dover.
AE231	ELEMENTS OF VIBRATION	2-0-0-0-2	Introduction: Particle dynamics for Rigid body dynamics: Planar and three-dimensional theory of vibrations: Single degree of freedom, multidegree of freedom systems; free and forced vibrations; modal analysis; eigen system analysis; response for general excitation; types of damping, proportional damping Principle of virtual work; Hamilton's Principle; Lagranges equations. **Course Reference**: 1. Engineering Mechanics: Dynamics (Fifth Edition): J.L. Meriam and L.G. Kraige, John Wiley and Sons.2. Elements of vibration analysis: L. Meirovitch, McGrawHill International Editions3. Theory of vibration with applications: W.T. Thomson and M.D. Dalleh, Prentice Hall4. Mechanical Vibrations: S.S Rao, Pearson Education.
AE232	AIRCRAFT STRUCTURES - I	3-0-0-1-4	Static equilibrium, determinate and indeterminate structures, static stability concepts, planar and space trusses. Beams bending & extension, stress resultants, modulus weighted section properties, bending shear stresses solid and open section. Idealization of stiffened shells. Shear center, shear flow in thin walled multicell box beams, effect of taper. Tasian of then walled Section Work and energy principles, strain energy and complementary strain energy, potential and complementary potential theorems, unit load method, reciprocal theorem. Application of energy principles for analysis of determinate and indeterminate structures.
AE251A	EXPERIMENTS IN AEROSPACE ENGINEERING-I	2-0-2-0-8	Content Principles of measurement Introduction Description of Measuring Instruments Performance Characteristics of Instruments, Calibration, Accuracy, Precision, Bias, Dynamic response Virtual Instrumentation and Data acquisition Introduction to VI Graphical programming using LABView: Vis and sub Vis, loops ,arrays, clusters, file I/O Data acquisition: ADC, DAC, DIO, serial and GPIB communication Motion control system Sensors Strain Gage Motion Force, Torque, Power Pressure and Sound Temperature and Heat Flux Flow Error analysis and data reduction Uncertainties in measurements Probability distributions Propagation of errors Estimates of Mean and Errors Curve fits Advanced Optical Measurements (PIV, LDV,etc.).

			Course Reference:1. Measurement Systems Application and Design, E. O. Doebelin; 2. Data Reduction and Error Analysis for Physical Sciences, P. R. Bevington and D. K. Robinson; 3. Experimental Stress Analysis, James W. Dally, William F. Riley; 4. Mechanical Behavior of Materials, Norman E. Dowling
AE311	AERODYNAMICS - II	3-1-0--4	Review of thermodynamics Governing equations of compressible flow Isentropic flow. Area Mach number relation. Speed of sound, Mach cone, Flow regimes in terms of Mach number Stationary and moving normal shock, Rankine Hugoniot relations. Oblique shock, Prandt lMeyer expansion Reflection, intersection of shocks and expansion waves Converging diverging nozzle, supersonic wind tunnel 1D unsteady flow: Riemann problem Method of characteristics Small perturbations applied to, subsonic & supersonic airfoils, slender bodies. Similarity rules and area rule Curved shock and Crocc's Theorem Shock Boundary layer interaction Transonic small perturbation (TSP) equations Transoonic full potential equations Rayleigh & Fanno flow Experimental techniques Introduction to hypersonics. **Course Reference**: 1. Elements of gas dynamics: Leipmann and Roshko, John Wiley and Sons; 2. The dynamics and thermodynamics of compressible flows: A. H Shapiro, John Wileyand Sons.
AE311A	COMPRESSIBLE AERODYNAMICS	3-0-0-0-9	Review of thermodynamics (2HRS) Governing equations of compressible flow (2HRS) Isentropic flow, Area Mach number relation (3 HRS) Speed of sound, Mach cone, Flow regimes in terms of Mach number (1 HRS) Stationary and moving normal shock, Rankine Hugoniot relations (2 HRS) Oblique shock, Prandtl Meyer expansion (3 HRS) Reflection, intersection of shocks and expansion waves (2 HRS) Converging diverging nozzle, supersonic wind tunnel (2 HRS) 1D unsteady flow: Riemann problem (2 HRS) Method of characteristics (2 HRS) Small perturbations applied to, subsonic & supersonic airfoils, slender bodies. (3 HRS) Similarity rules and area rule (2 HRS) Curved shock and Croccos Theorem (1 HRS) Shock Boundary layer interaction (1 HR) Transonic small perturbation (TSP) equations (2 HRS) Transonic full potential equations (2 HRS) Rayleigh & Fanno flow (2 HRS) Experimental techniques (2 HRS) Introduction to hypersonics (2 HRS) *Elements of gasdynamics: Leipmann and Roshko, John Wiley and Sons. The dynamics and thermodynamics of compressible flows: A. H Shapiro, John Wileyand Sons.
AE312	AERODYNAMICS-II	3-0-0-1-4	Dynamics & thermodynamics of 1D flow, isentropic flow, 1D wave: normal shock, central expansion. Supersonics, oblique shock, 2D steady flows: reflection, intersection; PrandtlMeyer flow. Method of characteristics. Small perturbations applied to, subsonic & supersonic airfoils, slender body. Similarity rules. Transonic area rule. Hypersonics; similitude, high temp and rarefaction.
AE321	FLIGHT MECHANICS -	3-0-0-1-4	Standard atmosphere Definition of altitude, relation between

	I		geo-potential and geometric altitudes, pressure, temperature, density altitudes 1Airfoil nomenclature, Airfoil data, infinite Vs finite wings, critical mach number, drag divergence mach number, wave drag, swept wings. Aerodynamic properties of wings and components;3.Airplane drag estimation for subsonic and supersonic flight regime for fuselage, wings, tail and other components of aircraft 3Flaps mechanism of high lift, estimation of CL, CD, CLICD, for different flaps at various configurations.2Aircraft power plants 4Introduction to drag polar, equations of motion, thrust required for level and unaccelerated flight, thrust available and maximum velocity, power required for level and unaccelerated flight, power available and maximum velocity (reciprocating engine propeller combination, jet engine), altitude effects on power required and available. Rate of climb, gliding flight, absolute and service ceiling, time to climb, range and endurance propeller driven airplane, range and endurance jet air plane, take off and landing performance, turning flight and the Vn diagram, accelerated rate of climb (energy method), special consideration for supersonic airplane20Optimal performance of airplanes 5Introduction to performance estimation of fixed wing Unmanned aerial Vehicles. **Course Reference**: 1. Introduction to Flight: J.D. Anderson, McGraw Hill International Editions; 2. Miele, A; Flight Mechanics Theory of Flight Paths, Vol.I; AddisonWesley, Reading, MA; 3. Tewari, A; Atmospheric and Space Flight Dynamics, Birkhauser, Boston, 2006; 4. Mechanics of Flight: Warren F. Phillips. John Wiley and Sons, Inc
AE321A	FLIGHT MECHANICS	3-0-0-0-9	Standard atmosphere Definition of altitude, relation between geopotential and geometric altitudes, pressure, temperature, density altitudes Airfoil nomenclature, Airfoil data, infinite vs finite wings, critical mach number, drag divergence mach number, wave drag, swept wings. Aerodynamic properties of wings and components Airplane drag estimation for subsonic and supersonic flight regime for fuselage, wings, tail and other components of aircraft Flaps mechanism of high lift, estimation of CL, CD, CL/CD, for different flaps at various configurations. Aircraft power plants Introduction to drag polar, equations of motion, thrust required for level and unaccelerated flight, thrust available and maximum velocity, power required for level and unaccelerated flight, power available and maximum velocity (reciprocating engine propeller combination, jet engine), altitude effects on power required and available. Rate of climb, gliding flight, absolute and service ceiling, time to climb, range and endurance propeller driven airplane, range and endurance jet airplane, take off and landing performance, turning flight and the Vn diagram, accelerated rate of climb (energy method), special consideration for supersonic airplane Optimal performance of airplanes Introduction to performance estimation of fixed wing unmanned aerial Vehicles

			Course Reference: 1. Introduction to Flight: J.D. Anderson, McGraw Hill International Editions. Miele, A; 2. Flight Mechanics Theory of Flight Paths, Vol.I AddisonWesley, Reading, MA. Tewari, A; 3. Atmospheric and Space Flight Dynamics, Birkhauser, Boston, 2006; Mechanics of Flight: Warren F. Phillips. John Wiley and Sons, Inc
AE322	FLIGHT MECHANICS-II	1-0-3-0-3	Definition of stability and control static stability and dynamic /stability. Moments on an airplane. Definition of pitch angle, flight path angle and angle of attack. Criteria for longitudinal and staticstability. Aerodynamic model (longitudinal mode), Longitudinal staticstability and control, contribution of the wing, tai fuselage to total moment about CG of aircraft. Equations of longitudinal staticstability. Calculation of elevator angle to trim in stick fixed vs stick free longitudinal static stability, estimation of neutral point (both stick fixed and stick free), estimation of static margin, estimation of maneuvering point (both stick fixed and stick free). Directional static stability, lateral static stability, estimation of static margin, estimation of trim condition Equations of airplane motion 3Concept of stability and control derivatives. Longitudinal and lateral directional dynamic modes Airplane response to controls 4Introduction to flying qualities and stability augmentation systems. **Course Reference**: 1. Flight Stability and Automatic Control: R. Nelson, McGraw Hill Education; 2. Introduction to Flight: J.D. Anderson, McGraw Hill International Editions; 3. Elkin, B; Dynamics of Flight: Stability and Control, 3rd ed., Wiley, New York, 1995; 4. Mechanics of Flight: Warren F. Phillips. John Wiley and Sons, Inc
AE322A	AIRCRAFT CONTROL SYSTEMS	3-0-0-0-9	Definition of stability and control static stability and dynamicstability. Moments on an airplane. Definition of pitch angle, flightpath angle and angle of attack. Criteria for longitudinal and static stability Aerodynamic model (longitudinal mode), Longitudinal staticstability and control, contribution of the wing, tail, fuselage to total moment about CG of aircraft. Equations of longitudinal staticstability. Calculation of elevator angle to trim in stick fixed vsstick free longitudinal static stability, estimation of neutral point (both stick fixed and stick free), estimation of static margin, estimation of maneuvering point (both stick fixed and stick free). Directional static stability, lateral static stability, estimation ofstatic margin, estimation of trim condition Equations of airplane motion Concept of stability and control derivatives Longitudinal and lateral directional dynamic modes Airplane response to controls Introduction to flying qualities and stability augmentation system. **Course Reference**: 1. Flight Stability and Automatic Control: R. Nelson, McGraw Hill Education. 2. Introduction to Flight: J.D. Anderson, McGraw Hill International Editions. Etkin, B., 3. Dynamics of Flight: Stability and Control 3rd ed., Wiley, New York, 1995*. 4. Mechanics of Flight: Warren F. Phillips. John Wiley and Sons, Inc

AE331	EXPERIMENTS IN STRUCTURES	1-0-3-0-3	Loads on an aircraft. Elements of Linear Theory of Elasticity for Idealization of Aerospace Structure; 1. Stress Resultant; 2. Extension bending of nonhomogenous Euler Bernoulli, Bending shear stress (open closed SE422 solid) St. Venant torsion of arbitrary crosssection 3. Shear flow; Thin Walled beams: Single celled and multi celled box beams. Shear center for open and closed section. Tapered beams Beam Column Euler Buckling Principle of virtual work **Course Reference**: 1. Theory and analysis of flight structures: R.M. Rivello.No. of lectures; 2, Aircraft Structures for Engineering Students (Fourth edition): T.H.G. Megson, Elsevier Aerospace Engineering Series; 3. Analysis of Aircraft Structures (second edition): B.K. Donaldson, CambridgeAerospace Series.
AE331A	INTRODUCTION TO AEROSPACE STRUCTURES	3-0-0-0-9	Loads on an aircraft (2 HRS) Elements of Linear Theory of Elasticity (4 HRS) Idealization of Aerospace Structure (1 HR) Stress Resultant (2 HRS) Extension bending of nonhomogenous Euler Bernoulli (4 HRS) Bending shear stress (open closed solid) (2 HR) St. Venant torsion of arbitrary crosssection (3 HR) Shear flow (2 HR) Thin Walled beams: Single celled and multi celled box beams. (5HR) Shear center for open and closed section (4 HR) Tapered beams (2 HRS) Beam Column Euler Buckling (5 HRS) Principle of virtual work (4 HRS) **Course Reference**: 1. Theory and analysis of flight structures: R.M. Rivello; Aircraft Structures for Engineering Students (Fourth edition); T.H.G. Megson, Elsevier Aerospace Engineering Series; 2. Analysis of Aircraft Structures (second edition): B.K. Donaldson, Cambridge Aerospace Series.
AE332	AEROSPACE STRUCTURES-II	0-0-2-0-2	Buckling of columns. Differential equation approach, energy approach, approximate techniques. Beam columns. Buckling strength of flat sheets in compression, combined stress. Local buckling of composite shapes. Buckling of sheet stiffener combination.
AE332A	AEROSPACE STRUCTURES-II	0-0-2-0-2	Buckling of columns. Differential equation approach, energy approach, approximate techniques. Beam columns. Buckling strength of flat sheets in compression, combined stress. Local buckling of composite shapes. Buckling of sheet stiffener combination.
AE341	PROPULSION - I	3-0-0-1-4	Introduction to Principle of Propulsion Air breathing and Rocket Propulsion, reading assignment and Home work on Basic Fluid Mechanics, Thermodynamics and Compressible Flows should be zivenAero Thermodynamics of Gas Turbine Engines. Introduction Type of Airbreathing jet engines, Performance of Gas Turbine Engines (thrust, efficiency, range) Cycle Analysis of Airbreathing Jet Engines (Ideal and Aetna! Cycles). Ramjet Turbojet Turbofan Turboprop Turbo shaft Air Intakes Rocket Propulsion. Introduction Single and multiStage Rockets Performance of Chemical Rockets. Principle of Combustion Estimation of Adiabatic Flame Temperature. Thrust Coefficient Characteristic Velocity Types of Nozzles and Efficiencies Gas Turbine Combustors and Afterburners.

			Course Reference: 1. Mechanics and Thermodynamics of Propulsion, P. Hill and C. Peterson; 2. Gas Turbine Theory, H. Cohen, G. F. C. Rogers, H. I. H. Saravanamuttoo; 3. Jet Propulsion, N. Cumpsty; 4. Rocket Propulsion Elements, G. P. Sutton and D. M. Ross; 5. Modern Compressible Flow, J. D. Anderson, McGraw Hill; 6. Fundamentals of Combustion, D.P. Mishra, Prentice Hall ofIndia, New Delhi, revisededition, 2010; 7. Gas Turbine Propulsion, D.P. Mishra, Annamaya Publisher, New Delhi 20 II
AE341A	AEROSPACE PROPULSION	3-0-0-2-11	Introduction- Principle of propulsion & middot; Air-breathing and rocket propulsion · Reading assignment and home work on basic fluid mechanics, thermodynamics and compressible flows. Aero-thermodynamics of gas turbine engines · Introduction: Type of air-breathing jet engines; Performance of gas turbine engines (Thrust, efficient, range). Cycle analysis of air-breathing jet engines (ideal and actual cycles); Ramjet; Scramjet; Turbojet; Turbofan; Turboprop; Turboshaft. Jet engines (ideal and actual cycles); Ramjet; Scramjet; Turbojet; Turbofan; Turboprop; Turboshaft. Introduction to turbo-machinery; Types of turbomachinery; Conservation of angular momentum. Centrifugal compressors; Principle of operation; Stage dynamics and cascade; Efficiency and losses; Compressor characteristics; Rotating stall and surge. Axial compressors; Principle of operation; Stage dynamics · Multi staging; Radial equilibrium; Efficiency and characteristics. Axial turbines · Elementary theory; Stage dynamics; Efficiency and losses; Blade cooling; Compressor-turbine matching. Gas turbine combustors and after-burners.
AE342	PROPULSION-II	3-0-3-1-5	Elements of combustion: adiabatic flame temperature, flammability and stability limits. Gas turbine combustors & after burners. Nozzles types & nonideal flows, Chemical rockets: Rocket vehicle mechanics, multistaging, propellants, heat transfer and cooling. Rocket ramjet. Measurements of volumetric flow rate, speed, torque, power and temperature. Experiments on axial compressor unit, gas turbine unit, and continuous combustion unit, cascades and curved diffuser.
AE345A	SPACECRAFT GUIDANCE NAVIGATION AND CONTROL	3-0-0-0-9	Attitude dynamics and stability of three axis stabilized, singlespin, dualspin, and multibody spacecraft with alticulated antennas, sensors, and solar arrays. Design of control of three axis stabilized spacecraft in orbit using reaction wheels, thrusters, magnets, single and double gimbaled control moment gyros Large angle three axis attitude maneuver controllers using reaction wheels and thrusters Control of spinning spacecraft in transfer orbit during delta_ v firing and in operational orbits around the Earth, and design of active nutation control Attitude stabilization of bias momentum spacecraft using magnets and thrusters Dynamics and control of dualspin spacecraft Precision pointing and tracking controllers for tracking landmarks, moving objects, and other satellites for crosslink communication Solar array controllers for tracking the Sun;

			determining the arrays orientation with sun sensors Modeling of dynamics of flexible solar arrays, its interaction with spacecraft dynamics and control systems Attitude determination with gyros, star trackers, sun sensors, and horizon sensors using algorithms such as TRIAD and QUEST (quaternion estimator); sensors error characteristics; and Kalman filtering Guidance and navigation for spacecraft rendezvous The above control techniques will be related with the control of Indian communication, remote sensing, and other special purpose satellites (Ca1tosat, Edusat, telemedicine). **Course Reference**: 1. Hughes, P.C., Spacecraft Attitude Dynamics, John Wiley, 1986; 2.Sidi, M.J., Spacecraft Dynamics and Control, Cambridge University Press, 1997 Noton, M;, 3. Spacecraft Navigation and Guidance, Springer 1998; 4.Kaplan, M.H., Modern Spacecraft Dynamics and Control, John Wiley, 1976; 5. Agrawal, B., Design of Geosynchronous Spacecraft, Prentice Hall, 1986; 6. Bryson, A.E., Control of Spacecraft and Aircraft, Princeton University Press, 1994; 7.Pocha, J.J., An Introduction to Mission Design for Geostationary Satellites, D. Reidel,1987; 8. Mara[, G., and Bousquet, M., Satellite Communications Systems, Fourth Edition, John Wiley, 2006; 9.Wie, B., Space Vehicle Dynamics and Control, AIAA Education Series, 1998
AE351A	EXPERIMENTS IN AEROSPACE ENGINEERING -II	0-0-4-1-5	Course content: Dimensional analysis, Wind tunnels, Basic Experiments with different sensors, Material characterization, Flow Visualization. About 12 experiments will be conducted in the course. The breakup of the experiments will be as follows: Aerospace Structures: 4-Low Speed Aerodynamics: 4 -Aerospace Propulsion: 2-High speed Aerodynamics: 2-List of Experiments: Aerospace Structures:1. Bending of beams; 2. Shear centre estimation;3. Estimation of Principal Axes; 4. Torsion; 5. UTM (static tests) Low Speed Aerodynamics:1. Laser light flow visualization; 2. Smoke flow visualization; 3. Hot wire anemometry (calibration + test); 4. Force balance calibration; 5. Calibration of low speed tunnel6. Flow past airfoil/circular cylinder Cp distribution. Aerospace Propulsion:1. Calibration and use of pressure sensors; 2. Calibration and use of thermocouples High Speed Aerodynamics:1. Schlieren + shadowgraphy; 2. Estimation of Mach number from static pressure measurement in supersonic tunnel. **Course Reference**: 1. Measurement Systems Application and Design, E. O. Doebelin; 2. Data Reduction and Error Analysis for Physical Sciences, P. R. Bevington and D. K. Robinson; 3. Experimental Stress Analysis, James W. Dally, William F. Riley; 4. Mechanical Behavior of Materials, Norman E. Dowling
AE361	AEROMODELLING DESIGN & FABRICATION	0-0-3-0-2	Design and fabrication of aero models/components; Balsa, Styrofoam, wood, parchment, composites ased model making; model upgradation; design, fabrication and testing of components; use of flight simulator, RC devices.

AE361A	AEROMODEL DESIGN & FABRICATION	0-0-3-0-3	Design and fabrication of aero models/components; Balsa, Styrofoam, wood, parchment, composites-based model making; model upgradation; design, fabrication and testing of components; use of flight simulator, RC devices. (40 hr). **Course Reference**: 1. Introduction to Flight: J.D. Anderson, Jr. McGrawHill International Editions. *Handouts. *Internet resources.
AE391A	UG PROJECT (UGP-I)	0-0-0-0-4	UG PROJECT (UGPI)
AE401A	TECHNICAL COMMUNICATION	0-0-2-2-2	Selection of topic of research or review; development of presentation material; preparation of technical report; technical presentations.
AE411	EXPERIMENTS IN AERODYNAMICS	2-0-3-0-4	Experiments and model testing. Similitude, flow visualization, low and high-speed tunnels: features & performance. Balances, Measurements; flow velocity: hotwire, laser doppler, pressure, temperature. Lab work: Set of experiments
AE421A	EXPERIMENTS IN FLIGHT MECHANICS	1-0-2-0-3	Introduction to fliaht testing and instrumentation 1. Techniques and data reduction methods, Error analysis 2. Calibration of flight and special flight test instruments: Evaluation of cruise and climb performance of a small airolane. Determination of static and maneuver stability and control characteristics. Observations of airplane dynamic modes and stall characteristics: Introduction to flight testing and instrumentation. Techniques and data reduction methods, Error analysis. Calibration of flight and special flight test instruments. Evaluation of cruise and climb performance of a small airplane. Determination of static and maneuver stability and control characteristics. Observations of airplane dynamic modes and stall characteristics.
AE422	EXPERIMENTS IN FLIGHT MECHANICS	1-0-2-0-2	Introduction to flight testing, instrumentation, techniques and data reduction methods, calibration of flight and special flight test instruments. Evaluation of glider drag polar. Evaluation of cruise and climb performance of a smallair plane. Determination of static and maneuvre stability and control characteristics. Observations of airplane dynamic modes and stall characteristics. Introduction to GPS based navigation. Introduction to autopilot.
AE441A	ROCKET PROPULSION	3-0-0-0-5	Rocket propulsion & ndash; Introduction, Single and multi-stage rockets. Performance of chemical rockets- Principles of combustion, Estimation of adiabatic flame temperature, Thrust coefficient, Characteristic velocity, Types of nozzles, efficiencies, cooling, heat transfer. Non-chemical rockets.
AE451	EXPERIMENTS IN AEROSPACE ENGINEERING	0-0-2-0-2	List of Experiments: Low Speed Aerodynamics Lab:1. Turbulence measurement; 2. Boundary Layer. Measurement; 3. Aerodynamic characterization of a model aircraft High Speed Aerodynamics Lab:1. Characterization of supersonic jets; 2. Forces and moments on a projectile at supersonic speeds Structures Lab: I. Experiments in photoelasticity; 2. Experiments in vibration; 3. Dynamic characterization of elastomeric materials 4. Inertia measurement Propulsion Lab: I. Characterization of intake; 2. Experiments in compressor/turbine cascades; 3.

			Performance analysis of 2 stage axial fan. Performance of gas turbine engine: Experiments in continuous combustion unit. **Course Reference**: 1. Measurement Systems Application and Design, E. 0. Doebelin; 2. Data Reduction and Error Analysis for Physical Sciences, P. R. Bevington and D. K. Robinson; 3. Experimental Stress Analysis, James W. Dally, William F. Riley; 4. Mechanical Behavior of Materials, Norman E. Dowling
AE451A	EXPERIMENTS IN AEROSPACE ENGINEERING III	0-0-3-2-5	List of Experiments: Low Speed Aerodynamics Lab:1. Turbulence measurement ;2.0 Boundary Layer. measurement3. Aerodynamic characterization of a model aircraf t High Speed Aerodynamics Lab:1. Characterization of supersonic jets; 2. Forces and moments on a projectile at supersonic speeds Structures Lab:I. Experiments in photoelasticity; 2. Experiments in vibration; 3. Dynamic characterization of elastomeric materials; 4. Inertia measurement Propulsion Lab:I. Characterization of intake; 2. Experiments in compressor/turbine cascades; 3. Performance analysis of 2stage axial fan; 4. Performance of gas turbine engine; 5. Experiments in continuous combustion unit **Course Reference**: 1. Measurement Systems Application and Design, E. 0. Doebelin; 2. Data Reduction and Error Analysis for Physical Sciences, P. R. Bevington and D. K. Robinson; 3. Experimental Stress Analysis, James W. Dally, William F. Riley; 4. Mechanical Behavior of Materials, Norman E. Dowling
AE461	AIRCRAFT DESIGN-I	2-0-4-0-5	Conceptual design based on preliminary mission requirements Survey of existing vehicular configurations (in similar category); lofting (preliminary layout sketches); preliminary weight estimation Selection of wing loading; thrust loading; wing section and plan form Fuselage layout and weight balance. Estimation of aerodynamic characteristics and performance evaluation Design of tail areas and control surfaces Estimation of span wise load distributions on wing and tail TOTAL LABORATORY OF THE COURSE Conceptual design based on preliminary mission requirements; survey of existing vehicular configurations (in similar category); lofting (preliminary layout sketches); preliminary weight estimation; selection of wing loading; thrust loading; wing section and plan form; fuselage layout and weight balance; estimation of aerodynamic characteristics and performance evaluation; design of tail areas and control surfaces; estimation of span wise load distributions on wing and tail. Aircraft Design: A Conceptual Approach, D. Raymer (4th Ed.), AIAA Press, 2006.
AE461A	AIRCRAFT DESIGN-I	1-0-2-2-7	Conceptual design based on preliminary mission requirements Survey of existing vehicular configurations (in similar category); lofting (preliminary layout sketches); preliminary weight estimation Selection of wing loading; thrust loading; wing section and plan form Fuselage layout and weight balance. Estimation of aerodynamic

			characteristics and performance evaluation Design of tail areas and control surfaces Estimation of span wise load distributions on wing and tail TOTAL LABORATORY OF THE COURSE Conceptual design based on preliminary mission requirements; survey of existing vehicular configurations (in similar category); lofting (preliminary layout sketches); preliminary weight estimation; selection of wing loading; thrust loading; wing section and plan form; fuselage layout and weight balance; estimation of aerodynamic characteristics and performance evaluation; design of tail areas and control surfaces; estimation of span wise load distributions on wing and tail. Aircraft Design: A Conceptual Approach, D. Raymer (4th Ed.), AIAA Press, 2006.
AE462	AIRCRAFT DESIGN-II	2-0-4-0-5	Concepts of structural design; Vn diagram; airworthiness requirements Stress resultants for swept and unswept wings; application of modified beam theory Methods for wing stress analysis; yielding based design Buckling (of columns, panels and stiffened panels) based design of thin structures Rib spacing; sizing and preliminary layout of wing; margin of safety; advanced analysis (using FEM based commercial/open source software) for full wing. Total Laboratory component of the course: Topic Concepts of structural design; Vn diagram; airworthiness requirements; stress resultants for swept and unswept wings; application of modified beam theory; methods for wing stress analysis; yielding based design; buckling (of columns, panels and stiffened panels) based design of thin structures; ribspacing; sizing and preliminary layout of wing; margin of safety; advanced analysis (using FEM based commercial/open sources oftware) for full wing. **Course Reference**: 1. Analysis and design of Flight Vehicle Structures: E.F. Bruhn. 2.Airframe Structural Design: M. Niu*. Aircraft Design: A Conceptual Approach, D. Raymer (4th Edition), AIAA Press,2006.
AE462A	AIRCRAFT DESIGN-II	1-0-1-0-4	Concepts of structural design; Vn diagram; airworthiness requirements Stress resultants for swept and unswept wings; application of modified beam theory Methods for wing stress analysis; yielding based design Buckling (of columns, panels and stiffened panels) based design of thin structures Rib spacing; sizing and preliminary layout of wing; margin of safety; advanced analysis (using FEM based commercial/open source software) for full wing. Total Laboratory component of the course: Topic Concepts of structural design; Vn diagram; airworthiness requirements; stress resultants for swept and unswept wings; application of modified beam theory; methods for wing stress analysis; yielding based design; buckling (of columns, panels and stiffened panels) based design of thin structures; rib spacing; sizing and preliminary layout of wing; margin of safety; advanced analysis (using FEM based commercial/opensources oftware) for full wing. **Course Reference**: 1. Analysis and design of Flight Vehicle Structures: E.F. Bruhn; 2. Airframe Structural Design: M.

			Niu; 3. Aircraft Design: A Conceptual Approach, D. Raymer (4th Edition), AIAA Press,2006.
AE471	PROJECT-I	0-0-0-0-2	Registration for project with the selection of topic & getting started on the design, fabrication work, algorithm etc.
AE471A	B TECH PROJECT	0-0-0-0-9	Registration for project with the selection of topic & getting started on the design, fabrication work, algorithm etc.
AE472	PROJECT-II	0-0-0-0-4	Continuation of the project work initiated as a part of project I and completion.
AE481	BOUNDARY LAYER THEORY	3-0-0--4	Conclusions from small BL thickness, BL eqns, exact and similar solutions: Blasius, Howarth & Merk. Methods: continuation & integral conditions, Polhausen, Walz, Weighardt. Axisymm BL. Mangler transformation, elementary 3D BL., Transition, turb BL. Walz integral method. BL control.
AE481A	BOUNDARY LAYER THEORY	3-0-0-0-9	Conclusions from small BL thickness, BL eqns, exact & similar solns: Blasius, Howarth & Merk. Methods: continuation & integral conditions, Polhausen, Walz, Weighardt. Axisymm BL. Mangler transformation, elementary 3D BL., Transition, turb BL. Walz integral method. BL control.
AE601	INTRO TO AEROSPACE ENGG.	3-0-0-0-4	History of aviation. History of spaceflight. Earths atmosphere and gravitational field. Anatomy of Flight vehicles. Bluff bodies v/s streamlined body, airfoil. Lift generation, significance of L/D ratio. Aerodynamic forces. Propulsion. Spacecrafts. Aircraft performance. Aerospace materials. Structural layout. Flight envelope and Vn diagrams. Instruments and navigational aids. Exposure to flight testing.
AE601A	INTRO TO AEROSPACE ENGG.	3-0-0-0-9	History of aviation. History of spaceflight. Earths atmosphere and gravitational field. Anatomy of Flight vehicles. Bluff bodies v/s streamlined body, airfoil. Lift generation, significance of L/D ratio. Aerodynamic forces. Propulsion. Spacecrafts. Aircraft performance. Aerospace materials. Structural layout. Flight envelope and Vn diagrams. Instruments and navigational aids. Exposure to flight testing.
AE602	MATHEMATICS FOR AEROSPACE ENGG.	3-0-0-0-4	Matrices, determinants, vector spaces, linear transformation, eigen systems, linear equations, introduction to ordinary differential equations, homogeneous linear equations of second order, nonhomogeneous linear equations of second order, free and forced oscillation problems, problems with variable coefficients, systems of equations, Fourier series, Fourier transform, Laplace transform, introduction to differencing methods; basic concepts of partial differential equations, classification of second order equations, wave propagation in one dimension, parabolic equations, higher dimensional problems, Laplace equation, series solutions, transform methods, elements of complex variables.
AE602A	MATHEMATICS FOR AEROSPACE ENGG.	3-0-0-0-9	differential equations, homogeneous linear equations of second order, nonhomogeneous linear equations of second order, free and forced oscillation problems, problems with

			variable coefficients, systems of equations, Fourier series, Fourier transform, Laplace transform, introduction to differencing methods; basic concepts of partial differential equations, classification of second order equations, wave propagation in one dimension parabolic equations, higher dimensional problems, Laplace equation, series solutions, transform methods, elements of complex variables.
AE603	INTRODUCTION TO SCIENTIFIC COMPUTING	2-0-1-0-4	Basics of Computing & Discretization, Errors: Different types of error, Interpolation and extrapolation, Root finding: Polynomials; Newton Raphson Method, Secant Method, ODE and their computations, Stiff ODEs & parasitic error, Solution of IVP (ODE), Linear Algebra & BVP(ODE), Solution of Linear System, Finding eigenvalue/eigenvector **Course Reference**: 1. Computational Fluid Dynamics: Charles Hirsch, Wiley, Chichester, U.K. (1990); 2. Computational Fluid Dynamics and heat transfer: J.C. Tannehill, D.A. Anderson and R.H. Fletcher, Taylor and Francis (1997); 3. Numerical Recipes in Fortran 77, W.H. Press, S. Teukolsky, W, Vetterling and B. Flannery, Cambridge Univ. Press (1992); 4. Foundation of CFD: Tapan K. Sengupta, University Press Hyderabad, India (2009).
AE603A	INTRODUCTION TO SCIENTIFIC COMPUTING	2-0-1-0-7	Basics of Computing & Discretization, Errors: Different types of error, Interpolation and extrapolation, Root finding: Polynomials; Newton Raphson Method, Secant Method, ODE and their computations, Stiff ODEs and parasitic error, Solution of IVP (ODE), Linear Algebra & BVP(ODE), Solution of Linear System, Finding eigenvalue/eigenvector. **Course Reference**: 1. Computational Fluid Dynamics: Charles Hirsch, Wiley, Chichester, U.K. (1990); 2. Computational Fluid Dynamics and heat transfer: J.C. Tannehill, D.A. Anderson and R.H. Fletcher, Taylor and Francis (1997); 3. Numerical Recipes in Fortran 77, W.H. Press, S. Teukolsky, W, Vetterling and B. Flannery, Cambridge Univ. Press (1992); 4. Foundation of CFD: Tapan K. Sengupta, University Press Hyderabad, India (2009).
AE604	COMPUTATIONAL FLUID MECHANICS	3-0-1-0-5	Basics of Governing Equations, Spacetime discretization for PDE, Classification of PDE, Grid Generation, Waves and disturbances in fluid flow, Spacetime scales in fluid flow, Classical methods for solving parabolic PDEs, Methods for solving elliptic PDEs, High accuracy methods, Time Discretization, Error analysis: DNS, LES, Solution of Navier Stokes equations. **Course Reference**: 1. Computational Fluid Dynamics: C. Hirsch, Wiley (1998); 2. Computational Fluid Flow and Heat Transfer, Tannehill, Anderson, Pletcher; 3. High Accuracy Computing Method: Fluid flow and wave phenomena: Tapan K. Sengupta, Cambridge University Press (2013); 4. Foundation of CFD: Tapan K Sengupta, Universities Press, Hyderabad, India (2004)
AE604A	COMPUTATIONAL FLUID MECHANICS	3-0-0-0-9	Basics of Governing Equations, Spacetime discretization for PDE, Classification of PDE, Grid Generation, Waves and

			disturbances in fluid flow, Spacetime scales in fluid flow, Classical methods for solving parabolic PDEs, Methods for solving elliptic PDEs, High accuracy methods, Time Discretization, Error analysis: DNS, LES, Solution of Navier Stokes equations. **Course Reference**: 1. Computational Fluid Dynamics: C. Hirsch, Wiley (1998);2. Computational Fluid Flow and Heat Transfer, Tannehill, Anderson, Pletcher; 3. High Accuracy Computing Method: Fluid flow and wave phenomena: Tapan K. Sengupta, Cambridge University Press (2013); 4. Foundation of CFD: Tapan K Sengupta, Universities Press, Hyderabad, India (2004)
AE605	ADVANCED COMPUTATIONAL FLUID MECHANICS	3-0-1-0-5	Issues of spacetime Resolution, Computing time averaged unsteady problem, Defference type of high Modeling RANS, URANS, LES, DES, DNS, Generalized transformation: Orthogonal/ Nonorthogonal grid, Chimera Technique, Basis of FDM, FVM, EEM, FDM and FVM: High accuracy methods. **Course Reference**: 1. Computational Fluid Dynamics: Charles Hirsch, Wiley, Chichester, U.K. (1990); 2. Computational Fluid Dynamics and heat transfer: J.C. Tannehill, D.A. Anderson and R.H. Fletcher, Taylor and Francis (1997); 3. Foundation of CFD: Tapan K. Sengupta, University Press Hyderabad, India (2009).
AE605A	ADVANCED COMPUTATIONAL FLUID MECHANICS	3-0-0-0-9	Issues of space time Resolution, Computing time averaged unsteady problem, Defference type of high Modeling RANS, URANS, LES, DES, DNS, Generalized transformation: Orthogonal/Nonorthogonal grid, Chimera Technique, Basis of FDM, FVM, EEM, FDM and FVM: High accuracy methods. **Course Reference**: 1. Computational Fluid Dynamics: Charles Hirsch, Wiley, Chichester, U.K. (1990); 2. Computational Fluid Dynamics and heat transfer: J.C. Tannehill, D.A. Anderson and R.H. Fletcher, Taylor and Francis (1997); 3. Foundation of CFD: Tapan K. Sengupta, University Press Hyderabad, India (2009).
AE610	AERODYNAMICS-I	3-0-0-0-4	Basic fluid mechanics Navier stokes equation, vorticity kinematics, Basic potential flows viscous flows including boundary layer theory, turbulence(introduction)
AE610A	AERODYNAMICS-I	3-0-0-0-9	Basic fluid mechanics Navier stokes equation, vorticity kinematics, Basic potential flows viscous flows including boundary layer theory, turbulence(introduction)
AE611	MEASUREMENTS IN FLUID MECHANICS	3-0-0-0-4	Introduction to measurement, Wind Tunnels and Water Tunnels, Flow visualization techniques, Measurement of Pressure and volume flow rate, Force Measurements, Temperature Measurements, Hotwire Measurements, Data Acquisition, Processing and uncertainty analysis, Static and dynamic response of measuring systems, PIV Measurements, Integral optical measurement techniques: Shadowgraph, Schlieren & Interferometers, LDV Measurements, LIF Measurements. Measurement of Wall Shear Stress. **Course Reference**: 1. Fluid Mechanics Measurement, by

			Richard J. Goldstein Springer Verlng. 1983; 2. Experimental Methods for Engineers by J.P. Holman McGrawHill 2008; 3. Measurement in Fluid Mechanics by Stavros Tavoularis. Cambridge 2005; 4. Particle Image Velocimetry: A Practical Guide by M. Raffel, C. Willert & J. Kompenhans. Springer, 1998; 5. Instrumentation, Measurements, and Experiments in Fluids, by E Rathakrishnan, CRCPress, 2007; 6. The Laser Doppler Technique, by L. E. Drain, John Wiley & Sons 1980; 7. Hotwire anemometry, by Perry A. E. Oxford University Press, 1982; 8. Particle Image Velocimetry, by Ronald J. Adrian and Jerry Westerweel Cambridge Aerospace Series, 2010.
AE611A	MEASUREMENTS IN FLUID MECHANICS	3-0-0-0-9	Introduction to measurement, Wind Tunnels and Water Tunnels, Flow visualization techniques, Measurement of Pressure and volume flow rate, Force Measurements, Temperature Measurements, Hotwire Measurements, Data Acquisition, Processing and uncertainty analysis, Static and dynamic response of measuring systems, PIV Measurements, Integral optical measurement techniques: Shadowgraph, Schlieren & Interferometers, LDV Measurements, LIF Measurements. Measurement of Wall Shear Stress. **Course Reference**: 1. Fluid Mechanics Measurement, by Richard J. Goldstein Springer Verlng. 1983; 2. Experimental Methods for Engineers by J.P. Holman McGrawHill 2008; 3. Measurement in Fluid Mechanics by Stavros Tavoularis. Cambridge 2005; 4. Particle Image Velocimetry: A Practical Guide by M. Raffel, C. Willert & J. Kompenhans. Springer, 1998; 5. Instrumentation, Measurements, and Experiments in Fluids, by E Rathakrishnan, CRCPress, 2007; 6. The Laser Doppler Technique, by L. E. Drain, John Wiley & Sons 1980; 7. Hotwire anemometry, by Perry A. E. Oxford University Press, 1982; 8. Particle Image Velocimetry, by Ronald J. Adrian and Jerry Westerweel Cambridge Aerospace Series, 2010.
AE612	AERODYNAMICS II	3-0-0--4	Thin aerofoil theory, finite wing theory, basic thermodynamics, one and two- dimensional flows, isentropic flows, waves (shock, expansion, characteristics etc.), potential flows, perturbation equation, subsonic flows similarities Fanno and Rayleigh flows.
AE612A	AERODYNAMICS II	3-0-0-0-9	Thin aerofoil theory, finite wing theory, basic thermodynamics, one and two-dimensional flows, isentropic flows, waves (shock, expansion, characteristics etc.), potential flows, perturbation equation, subsonic flows similarities Fanno and Rayleigh flows.
AE614	VISCOUS FLOWS	3-0-0--4	Basic concepts of BL theory; similar flows: generalized techniques of solving BL eqns. for incompressible fluids: thermal BL. BL control. Intro. to turbulent hear flows.
AE614A	VISCOUS FLOWS	3-0-0-0-9	Basic concepts of BL theory; similar flows: generalized techniques of solving BL eqns. for incompressible fluids: thermal BL. BL control. Intro. to turbulent shear flows.
AE615	ADVANCED COMPUTATIONAL	3-0-0--4	Main issues of space time resolution: Computing time averaged and unsteady problems. Discretization with

	METHODS IN CFD		operators. Problems in physical and transformed plane: Jacobians and flux vector splitting. Generalized transformation and grid generation techniques: Orthogonal and Chimera grids application to FIV/aero elasticity problems. Spectral tools of analysis for discrete schemes: FDM, FVM& FEM. High order and high accuracy schemes of FDMs and FVMs. Design of Dispersion Relation Preservation schemes. Aliasing error and its alleviation. High accuracy methods for DN Sand LES. SGS models for LES and their connection to higher order up winding. Computing equations with discontinuous solutions and Gibbs phenomenon. Applications to incompressible viscous and compressible flows. DNS of turbulence and acoustic problems.
AE615A	ADVANCED COMPUTATIONAL METHODS IN CFD	3-0-0-0-9	Main issues of space time resolution: Computing time averaged and unsteady problems. Discretization with operators. Problems in physical and transformed plane: Jacobians and flux vector splitting. Generalized transformation & grid generation techniques: Orthogonal & Chimera grids application to FIV/aero elasticity problems. Spectral tools of analysis for discrete schemes: FDM, FVM& FEM. High order and high accuracy schemes of FDMs and FVMs. Design of Dispersion Relation Preservation schemes. Aliasing error & its alleviation. High accuracy methods for DN Sand LES. SGS models for LES and their connection to higher order up winding. Computing equations with discontinuous solutions and Gibbs phenomenon. Applications to incompressible viscous and compressible flows. DNS of turbulence and acoustic problems.
AE617	BOUNDARY LAYER INSTABILITY AND TRANSITION	3-0-0--4	Navier Stokes eqn. and its various forms, thin shear layer approxn. Various types of flows. Instabilities in laminar flows. Relationship of instability theory with transition to turbulence. Transition prediction. Receptivity for two and three- dimensional problems.
AE617A	BOUNDARY LAYER INSTABILITY AND TRANSITION	3-0-0-0-9	Navier Stokes eqn. and its various forms, thin shear layer approxn. Various types of flows. Instabilities in laminar flows. Relationship of instability theory with transition to turbulence. Transition prediction. Receptivity for two and three -dimensional problems.
AE618	FINITE ELEMENT METHODS FOR FLUID DYNAMICS	3-0-0--4	Fundamental concepts; strong form, weak form, Galerkins approximation; matrix eqns, element and global point of view; numerical integration Guassian quadrature; termporal discretization generalized trapeziodal rule; compressible and incompressible flows; implementation of the methods; issues related to high performance computing.
AE618A	FINITE ELEMENT METHODS FOR FLUID DYNAMICS	3-0-0-0-9	Fundamental concepts; strong form, weak form, Galerkins approximation; matrix eqns, element and global point of view; numerical integration Guassian quadrature; termporal discretization generalized trapeziodal rule; compressible and incompressible flows; implementation of the methods; issues related to high performance computing.

AE621	TURBULENCE	3-0-0--4	Origin, examples and character of turb, Reynolds stress, energy relations, closure problem, phenomenology, eddy viscosity. Staistics. spectra, space time correlations, macro & micro scales, stat. theory of turb, locally isotropic turb, Kolmogorovs hypothesis, correlation method, spectral method, turb. diffusion. Experimental techniques.
AE621A	TURBULENCE	3-0-0-0-9	Origin, examples and character of turb, Reynolds stress, energy relations, closure problem, phenomenology, eddy viscosity. Staistics. spectra, space time correlations, macro & micro scales, stat. theory of turb, locally isotropic turb, Kolmogorovs hypothesis, correlation method, spectral method, turb. diffusion. Experimental techniques.
AE622	COMPUTATIONAL FLUID DYNAMICS	3-0-0--4	Eqns of fluid dynamics & its classifications. Boundary conditions. Stability analysis & concept of feedback. Various explicit & implicit schemes. Grid generation. Solving parabolic, elliptic PDEs by explicit, implicit, accelerated techniques. Solving advection equation. Integral representation of Navier Stokes equation; LES and DNS.
AE622A	COMPUTATIONAL FLUID DYNAMICS	3-0-0-0-9	Equations of fluid dynamics and its classifications. Boundary conditions. Stability analysis and concept of feedback. Various explicit & implicit schemes. Grid generation. Solving parabolic, elliptic PDEs by explicit, implicit, accelerated techniques. Solving advection equation. Integral representation of Navier Stokes equation; LES & DNS.
AE625	TRANSITION AND TURBULENCE	3-0-0--4	Elements of viscous flows and thin shear layer approximation. Different types of TSL flows. Instabilities in flows. Rayleigh Taylor, Kelvin Helmholtz mechanisms. Thin shear layer instabilities: for parallel and nonparallel flows. Temporal and spatial instabilities in boundary layers. convective/absolute, local/global instabilities of boundary layers, wakes, jets and free shear layers. Primary and secondary instabilities and relationship of instability theories to transition. Receptivity of shear layers for 2 and 3D flows. Bypass transition in different flows. Classified views of turbulent flows. Scales, spectra and closure of turbulent flows. Vorticity dynamics and other kinematic tools of turbulence. Role of stretching and dispersion in small scale turbulence. Route to turbulence: Chaos via nonlinearity, instabilities and bifurcation. Coherent structures in turbulence: Universality of transitional and turbulent flows. Study of turbulence via chaos dynamics and proper orthogonal decomposition (POD). DNS, LES and other closure schemes of turbulence **Course Reference**: 1. Drazin. P.G. & Reid W.H.: Hydrodynamic Stability 1981, (CUP); 2. Davidson. P.A.: Turbulence (2003) (OUP);3. Lmdahl. M.T. & Mollo Christcnsen: Turbulence & Random Processes in Fluid Mechanics 1992 (CUP); 4. Holmes. P., Lumley, J.L. & Bcrkooz G: Turbulence, Coherent structures. Dynamical systems and Symmetry. 1996 (CUP); 5. Sagaut. P.: Large Eddy Simulation for Incompressible Flows. 2000 (Springer); 6. Sengupta T.K.: Foundation of CFD, 2004 (Univ. Press)

AE625A	TRANSITION AND TURBULENCE	3-0-0-0-9	Elements of viscous flows and thin shear layer approximation. Different types of TSL flows. Instabilities in flows. Rayleigh Taylor, Kelvin Helmholtz mechanisms. Thin shear layer instabilities: for parallel and nonparallel flows. Temporal and spatial instabilities in boundary layers. convective/absolute, local/global instabilities of boundary layers, wakes, jets and free shear layers. Primary and secondary instabilities and relationship of instability theories to transition. Receptivity of shear layers for 2 and 3D flows. Bypass transition in different flows. Classified views of turbulent flows. Scales, spectra and closure of turbulent flows. Vorticity dynamics and other kinematic tools of turbulence. Role of stretching and dispersion in small scale turbulence. Route to turbulence: Chaos via nonlinearity, instabilities and bifurcation. Coherent structures in turbulence: Universality of transitional and turbulent flows. Study of turbulence via chaos dynamics ans proper orthogonal decomposition (POD). DNS, LES and other closure schemes of turbulence **Course Reference**: 1. Drazin. P.G. & Reid W.H.: Hydrodynamic Stability 1981, (CUP); 2. Davidson. P.A.: Turbulence (2003) (OUP);3. Lmdahl. M.T. & Mollo Christcnsen: Turbulence & Random Processes in Fluid Mechanics 1992 (CUP); 4. Holmes. P., Lumley, J.L. & Bcrkooz G.: Turbulence, Coherent structures. Dynamical systems and Symmetry. 1996 (CUP); 5. Sagaut. P.: Large Eddy Simulation for Incompressible Flows. 2000 (Springer); 6. Sengupta T.K.: Foundation of CFD, 2004 (Univ. Press)
AE628	CONTINUUM HYPERSONIC AERODYNAMICS	3-0-0--4	Continuum hypersonics in entry flight. Gen features, Mach no. Small disturb theory, similitude. Large diflecn similitude; wedge, cone, wing. Unified similitude. Lighthill & other piston analogies, Newton Busemann theory, thin shock layers, viscous inviscid interaction. Real gas. Frozen flow. Non equillibrium flow.
AE628A	CONTINUUM HYPERSONIC AERODYNAMICS	3-0-0-0-9	Continuum hypersonics in entry flight. Gen features, Mach no. Small disturb theory, similitude. Large diflection similitude; wedge, cone, wing. Unified similitude. Lighthill & other piston analogies, Newton Busemann theory, thin shock layers, viscous inviscid interaction. Real gas. Frozen flow. Nonequilibrium flow.
AE629	ADVANCES IN WIND ENERGY CONVERSION	3-0-0--4	Earths atmosphere & rotation, Coriolis force, geotrophic winds. Terrain, mettheories, measuring technique. Wind power site. Atmospheric BL. Aerodynamics in wind power. Sails, airscrews. Vertical & horizontal axis wind turbines. Actuator disc, momentum, and vortex theories. Control of wind turbines.
AE629A	ADVANCES IN WIND ENERGY CONVERSION	3-0-0-0-9	Earth's atmosphere & rotation, Coriolis force, geotrophic winds. Terrain, mettheories, measuring technique. Wind power site. Atmospheric BL. Aerodynamic in wind power. Sails, airscrews. Vertical & horizontal axis wind turbines. Actuator disc, momentum, and vortex theories. Control of wind turbines.
AE640	AUTONOMOUS	3-0-0-0-4	Course introduction, basic definition, notion, guidance,

	NAVIGATION		navigation, and control loops. Review to linear algebra. Coordinated frames, kinematics and dynamics, trim conditions. Linear control and autopilot design. Introduction to probability and random processes. Accelerometer, rate gyros, pressure sensors, magnetometers, inertial measurement units (IMUs), global positioning systems (GPS). State estimation: Kalman filter (KF), Extended Kalman filter (EKF), Unscented Kalman filter (UKF), Cubature Kalman filter (CKF), Information filters, GPS aided navigation. Path planning and path following algorithms. Controllability, observability, vision guided navigation. Cooperative control **Course Reference**: 1. D. P. Bertsekas and J. N. Tsitsiklis, Introduction to Probability, Athena Scientific, 2008; 2. S. Thrun, W. Burgard, and D. Fox, Probabilistic Robotics, MIT Press, 2005; 3. S. M. LaValle. Planning Algorithms. Cambridge University Press, Cambridge, U.K., 2006.
AE640A	AUTONOMOUS NAVIGATION	3-0-0-0-9	Course introduction, basic definition, notion, guidance, navigation, and control loops. Review to linear algebra. Coordinated frames, kinematics and dynamics, trim conditions. Linear control and autopilot design. Introduction to probability and random processes. Accelerometer, rate gyros, pressure sensors, magnetometers, inertial measurement units (IMUs), global positioning systems (GPS). State estimation: Kalman filter (KF), Extended Kalman filter (EKF), Unscented Kalman filter (UKF), Cubature Kalman filter (CKF), Information filters, GPS aided navigation. Path planning and path following algorithms. Controllability, observability, vision guided navigation. Cooperative control. **Course Reference**: 1. D. P. Bertsekas and J. N. Tsitsiklis, Introduction to Probability, Athena Scientific, 2008; 2. S. Thrun, W. Burgard, and D. Fox, Probabilistic Robotics. Cambridge University Press, Ca, MIT Press, 2005; 3. S. M. LaValle. Planning Algorithms mbridge, U.K., 2006.
AE641	SPACE DYNAMICS-I	3-0-0-0-4	Introduction, performance of single and multistage rockets, central force motion, two body problem, ballistic trajectories, trajectory transfer, rendezvous and interception, Eulers eqns, satellite attitude dynamics, stabilization through gravity gradient, spin and dual spin, effect of energy dissipation on stability.
AE641A	SPACE DYNAMICS-I	3-0-0-0-9	Introduction, performance of single and multistage rockets, central force motion, two body problem, ballistic trajectories, trajectory transfer, rendezvous and interception, Eulers eqns, satellite attitude dynamics, stabilization through gravity gradient, spin and dual spin, effect of energy dissipation on stability.
AE645	SPACECRAFT GUIDANCE NAVIGATION AND CONTROL	3-0-0--4	Attitude dynamics and stability of three axis stabilized, single spin, dual spin, and multi body spacecraft with a1ticulated antennas, sensors, and solar arrays. Design of control of three axis stabilized spacecraft in orbit using reaction wheels, thrusters, magnets, single and double gimbaled control moment gyros Large angle three axis

			attitude maneuver controllers using reaction wheels and thrusters Control of spinning spacecraft in transfer orbit during delta_ v firing and in operational orbits around the Earth, and design of active nutation control Attitude stabilization of bias momentum spacecraft using magnets and thrusters Dynamics and control of dual spin space craft Precision pointing and tracking controllers for tracking landmarks, moving objects, and other satellites for crosslink communication Solar array controllers for tracking the Sun; determining the arrays orientation with sun sensors Modeling of dynamics of flexible solar arrays, its interaction with spacecraft dynamics and control systems Attitude determination with gyros, star trackers, sun sensors, and horizon sensors using algorithms such as TRIAD and QUEST (quaternion estimator); sensors error characteristics; and Kalman filtering Guidance and navigation for spacecraft rendezvous The above control techniques will be related with the control of Indian communication, remote sensing, and other special purpose satellites (Ca1tosat, Edusat, telemedicine). **Course Reference**: 1. Hughes, P.C., Spacecraft Attitude Dynamics, John Wiley, 1986; 2. Sidi, M.J., Spacecraft Dynamics and Control, Cambridge University Press, 1997; 3. Noton, M., Spacecraft Navigation and Guidance, Springer 1998; 4. Kaplan, M.H., Modern Spacecraft Dynamics and Control, John Wiley, 1976; 5. Agrawal, B., Design of Geosynchronous Spacecraft, Prentice Hall, 1986; 6. Bryson, A.E., Control of Spacecraft and Aircraft, Princeton University Press, 1994; 7. Pocha, J.J., An Introduction to Mission Design for Geostationary Satellites, D. Reidel,1987; 8. Mara[, G., and Bousquet, M., Satellite Communications Systems, Fourth Edition, JohnWiley, 2006; 9. Wie, B., Space Vehicle Dynamics and Control, AIAA Education Series, 1998
AE645A	SPACECRAFT GUIDANCE NAVIGATION AND CONTROL	3-0-0-0-9	Course Details: Attitude dynamics and stability of three axis stabilized, single spin, dual spin, and multibody spacecraft with a1ticulated antennas, sensors, and solar arrays. Design of control of there axis stabilized spacecraft in orbit using reaction wheels, thrusters, magnets, single and double gimbaled control moment gyros Large angle three axis attitude maneuver controllers using reaction wheels and thrusters Control of spinning spacecraft in transfer orbit during delta_ v firing and in operational orbits around the Earth, and design of active nutation control Attitude stabilization of bias momentum spacecraft using magnets and thrusters Dynamics and control of dualspin spacecraft Precision pointing and tracking controllers for tracking landmarks, moving objects, and other satellites for crosslink communication Solar array controllers for tracking the Sun; determining the arrays orientation with sun sensors Modeling of dynamics of flexible solar arrays, its interaction with spacecraft dynamics and control systems Attitude determination with gyros, star trackers, sun sensors, and horizon sensors using algorithms such as TRIAD and

			QUEST (quaternion estimator); sensors error characteristics; and Kalman filtering Guidance and navigation for spacecraft rendezvous The above control techniques will be related with the control of Indian communication, remote sensing, and other special purpose satellites (Ca1tosat, Edusat, telemedicine). **Course Reference** : 1. Hughes, P.C., Spacecraft Attitude Dynamics, John Wiley, 1986; 2. Sidi, M.J., Spacecraft Dynamics and Control, Cambridge University Press, 1997; 3. Noton, M., Spacecraft Navigation and Guidance, Springer 1998; 4. Kaplan, M.H., Modern Spacecraft Dynamics and Control, John Wiley, 1976; 5. Agrawal, B., Design of Geosynchronous Spacecraft, Prentice Hall, 1986; 6. Bryson, A.E., Control of Spacecraft and Aircraft, Princeton University Press, 1994; 7. Pocha, J.J., An Introduction to Mission Design for Geostationary Satellites, D. Reidel,1987; 8. Mara[, G., and Bousquet, M., Satellite Communications Systems, Fourth Edition, JohnWiley, 2006; 9. Wie, B., Space Vehicle Dynamics and Control, AIAA Education Series, 1998
AE647	FLIGHT DYNAMICS	3-0-0-0-4	Fundamentals of vectors. Transformation of coordinates. Particle kinematics. Rigid body kinematics. Force equations in a moving frame. Moment equations in a moving frame. Atmospheric flight Dynamics. Space flight dynamics. Gyrodynamics.
AE647A	FLIGHT DYNAMICS	3-0-0-0-9	Fundamentals of vectors. Transformation of coordinates. Particle kinematics. Rigid body kinematics. Force equations in a moving frame. Moment equations in a moving frame. Atmospheric flight Dynamics. Space flight dynamics. Gyrodynamics.
AE648	FLIGHT STABILITY AND CONTROL	3-0-0-0-4	Linearized equations of aircraft motion for small perturbations in stability axes. Stability analysis of linearized equations of motion. Airplane longitudinal motion. Airplane lateral motion. Airplane handling qualities. Missile and launch vehicle stability and control. Qualitative discussion of automatic flight control systems
AE648A	FLIGHT STABILITY AND CONTROL	3-0-0-0-9	Linearized equations of aircraft motion for small perturbations in stability axes. Stability analysis of linearized equations of motion. Airplane longitudinal motion. Airplane lateral motion. Airplane handling qualities. Missile and launch vehicle stability and control. Qualitative discussion of automatic flight control systems
AE649	AUTOMATIC CONTROL OF AIRCRAFT ROCKETS AND SPACECRAFT	3-0-0--4	1. Introduction to Automatic Control Systems.(Plant Models, Control Algorithms, Sensors, Actuators, Control Systems Classification.); 2. Introduction to Rigid Body Dynamics and Flight Models; 3. Linear Systems (Analog and Digital Systems, Transfer Function and Frequency Response, State Space Representations, Stability, Performance, and Robustness); 4. Single Variable Linear Control(Proportional, Integral, Derivative Control, Rate and Rate Integrating Gyros, Single Input Regulation by Pole Placement, Linear Observers, SISO Compensation and Tracking, Single Axis Attitude Control, Aircraft Heading Autopilot, Aircraft Speed

			Autopilot, Roll Autopilots for Aircraft, Rockets, and Entry Vehicles, Planar Tracking Systems for Rockets and Entry Vehicles, Pitch Stabilization of Gravity Gradient Spacecraft, Spacecraft Single Axis Maneuvers); 5. Multivariable Linear Optimal Control(Linear Optimal Control, Linear Quadratic Regulator, Kalman Filter, Optimal Compensation and Multivariable Tracking, Longitudinal Autopilots for Aircraft, Bank to turn Missiles, and Entry Vehicles, Lateral Directional Autopilots for Atmospheric Flight Vehicles, Attitude Stabilization of Spacecraft, Reaction Wheel Control Systems, Magnetic Torquer/Reaction Wheel Control Systems, Control Moment Gyroscopes ,Variable Speed Control Moment Gyroscopes, Thrust Vectoring Attitude Control of Rockets); 6. Terminal Time Weighted Linear Optimal Control (Time Varying Tracking Systems, Guidance and Control of Rockets and Entry Vehicles, Automated Orbital Rendezvous); 7. Digital Implementation of Linear Flight Control Systems. **Course Reference**: 1. Tewari, A, Modern Control Design with MATLAB and Simulink, John Wiley & Sons, Chichester, 2002; 2. Tewari, A, Atmospheric and Space Flight Dynamics, Springer (Birkhauser), Boston, 2006.
AE649A	AUTOMATIC CONTROL OF AIRCRAFT ROCKETS AND SPACECRAFT	3-0-0-0-9	1. Introduction to Automatic Control Systems.(Plant Models, Control Algorithms, Sensors, Actuators, Control Systems Classification.); 2. Introduction to Rigid Body Dynamics and Flight Models; 3. Linear Systems(Analog and Digital Systems, Transfer Function and Frequency Response, State Space Representations, Stability, Performance, and Robustness); 4. Single Variable Linear Control(Proportional, Integral, Derivative Control, Rate and Rate Integrating Gyros, Single Input Regulation by Pole Placement, Linear Observers, SISO Compensation and Tracking, Single Axis Attitude Control, Aircraft Heading Autopilot, Aircraft Speed Autopilot, Roll Autopilots for Aircraft, Rockets, and Entry Vehicles, Planar Tracking Systems for Rockets and Entry Vehicles, Pitch Stabilization of Gravity Gradient Spacecraft, Spacecraft Single Axis Maneuvers); 5. Multivariable Linear Optimal Control(Linear Optimal Control, Linear Quadratic Regulator, Kalman Filter, Optimal Compensation and Multivariable Tracking, Longitudinal Autopilots for Aircraft, Banktoturn Missiles, and Entry Vehicles, Lateral Directional Autopilots for Atmospheric Flight Vehicles, Attitude Stabilization of Spacecraft, Reaction Wheel Control Systems, Magnetic Torquer/Reaction Wheel Control Systems, Control Moment Gyroscopes ,Variable Speed Control Moment Gyroscopes, Thrust Vectoring Attitude Control of Rockets); 6. Terminal Time Weighted Linear Optimal Control (Time Varying Tracking Systems, Guidance and Control of Rockets and Entry Vehicles, Automated Orbital Rendezvous); 7. Digital Implementation of Linear Flight Control Systems. **Course Reference**: 1. Tewari, A, Modern Control Design with MATLAB and Simulink, John Wiley & Sons, Chichester, 2002; 2. Tewari, A, Atmospheric and Space Flight

			Dynamics, Springer (Birkhauser), Boston, 2006.
AE650	FUNDAMENTAL OF AEROSPACE PROPULSION - I	3-0-0-0-4	Introduction to propulsion, conservation equations, basic thermodynamics, dynamics and thermodynamics of 1 D flows, 1 D isentropic flows, normal and oblique shocks, compressible flows, Rayleigh flow, Fanno flow, elements of combustion, thermochemistry, adiabatic flame temperature, premixed flames, diffusion flames, rocket propulsion, thrust equation, solid rockets, liquid rockets, hybrid rockets, gas turbine cycles.
AE650A	FUNDAMENTAL OF AEROSPACE PROPULSION - I	3-0-0-0-9	Introduction to propulsion, conservation equations, basic thermodynamics, dynamics and thermodynamics of 1 D flows, 1 D isentropic flows, normal and oblique shocks, compressible flows, Rayleigh flow, Fanno flow, elements of combustion, thermochemistry, adiabatic flame temperature, premixed flames, diffusion flames, rocket propulsion, thrust equation, solid rockets, liquid rockets, hybrid rockets, gas turbine cycles.
AE652	AIRCRAFT PROPULSION	3-0-0-0-4	Gas turbine engines, performance analysis, subsonic and supersonic diffusers, centrifugal and axial compressors, stage dynamics, compressor stall, axial turbines, compressor turbine matching, gas turbine combustors and after burners, nozzles, ramjets, scramjets.
AE652A	AIRCRAFT PROPULSION	3-0-0-0-9	Gas turbine engines, performance analysis, subsonic and supersonic diffusers, centrifugal and axial compressors, stage dynamics, compressor stall, axial turbines, compressor turbine matching, gas turbine combustors and after burners, nozzles, ramjets, scramjets.
AE653	THERMAL TURBOMACHINERY	3-0-0--4	Axial compressors, stage dynamics, degree of reaction, pressure rise limitations, secondary flows, performance: design and off design, starting problems, centrifugal compressors; inlet flow, slip, sweep, diffuser design. Axial turbines: stage dynamics, three dimensional flows, loss estimation, blade cooling.
AE653A	THERMAL TURBOMACHINERY	3-0-0-0-9	Axial compressors, stage dynamics, degree of reaction, pressure rise limitations, secondary flows, performance: design and off design, starting problems, centrifugal compressors; inlet flow, slip, sweep, diffuser design. Axial turbines: stage dynamics, three dimensional flows, loss estimation, blade cooling.
AE657	AIRBREATHING MISSILE PROPULSION	3-0-0-0-4	Introduction and overview. Comparison of ramjet propulsion with other types of missile propulsion. Types of ram propulsion. Specific impulse. Propellants. Ramjet air induction system for missile application. Ducted rocket performance with single and multiple inlet systems. Engine and airframe integration for ramjet and ram rocket powered missiles. Ramjet with solid fuel. Solid propellant ram rockets. Supersonic combustion ramjet. Inlet, combustor and nozzle analysis.
AE657A	AIRBREATHING MISSILE PROPULSION	3-0-0-0-9	Introduction and overview. Comparison of ramjet propulsion with other types of missile propulsion. Types of ram propulsion. Specific impulse. Propellants. Ramjet air induction system for missile application. Ducted rocket

			performance with single and multiple inlet systems. Engine and airframe integration for ramjet and ram rocket powered missiles. Ramjet with solid fuel. Solid propellant ramrockets. Supersonic combustion ramjet. Inlet, combustor and nozzle analysis.
AE658	NUMERICAL MODELING OF CHEMICALLY REACTING FLOWS	3-1-0-0-5	Introduction, Governing equations, Modeling of laminar premixed and nonpremixed flames, Modeling of turbulent premixed and nonpremixed flames, Advanced modeling aspect. Introduction (3 hrs) Motivation and aim Governing equations for reacting flows Modeling of Laminar Premixed flames (7 hrs) Introduction Conservation equations and numerical solutions Steady 1 D flames Theoretical solution methods Calculation of flame speed, thickness and stretch Modeling of Laminar non premixed flames (6 hrs) Non premixed flame configuration Theoretical tools Flame structure for irreversible infinite fast chemistry and solutions Theory of other flame structures Modeling of turbulent premixed flames (10 hrs) Phenomenological description Premixed turbulent combustion regime RANS modeling LES modeling DNS modelling Modeling of turbulent non premixed flames (10 hrs) Phenomenological description Turbulent non premixed combustion regime RANS modeling LES modeling DNS modelling Advanced modeling aspect (4 hrs) Combustion in two phase flows Boundary conditions Flame/wall interactions Flame/acoustics interaction. **Course Reference**: 1. Peters, N., Turbulent Combustion, Cambridge University Press, 2000; 2. Warnatz, J., Mass, U., Dibble, R.W., Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation, Springer, 4111 Edition, 2006; 3. Kuo, Kenneth, Principles of Combustion, John Wiley and Sons, Inc, Edition,2005; 4. Chung, T. J., Computational Fluid Dynamics, Cambridge University Press, 2002; 5. Law, C. K., Combustion Physics, Cambridge University Press, 2006.
AE658A	NUMERICAL MODELING OF CHEMICALLY REACTING FLOWS	3-0-0-0-9	Introduction, Governing equations, Modeling of laminar premixed and nonpremixed flames, Modeling of turbulent premixed and nonpremixed flames, Advanced modeling aspect. Introduction (3 hrs) Motivation and aim Governing equations for reacting flows Modeling of Laminar Premixed flames (7 hrs) Introduction Conservation equations and numerical solutions Steady 1 D flames Theoretical solution methods Calculation of flame speed, thickness and stretch Modeling of Laminar non premixed flames (6 hrs) Non premixed flame configuration Theoretical tools Flame structure for irreversible infinite fast chemistry and solutions Theory of other flame structures Modeling of turbulent premixed flames (10 hrs) Phenomenological description Premixed turbulent combustion regime RANS modeling LES modeling DNS modelling Modeling of turbulent non premixed flames (10 hrs) Phenomenological description Turbulent nonpremixed combustion regime RANS modeling LES modeling DNS modelling Advanced modeling aspect (4 hrs) Combustion in two phase flows Boundary conditions

			Flame/wall interactions Flame/acoustics interaction. **Course Reference**: 1. Peters, N., Turbulent Combustion, Cambridge University Press, 2000; 2. Warnatz, J., Mass, U., Dibble, R.W., Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation, Springer, 4111 Edition, 2006; 3. Kuo, Kenneth, Principles of Combustion, John Wiley and Sons, Inc, 2nd Edition,2005; 4. Chung, T. J., Computational Fluid Dynamics, Cambridge University Press, 2002; 5. Law, C. K., Combustion Physics, Cambridge University Press, 2006.
AE660	PRELIMINARY DESIGN OF HELICOPTER	2-0-3-0-4	1. Introduction to: design process, design goals, types of rotorcraft (2 Lec.); 2. Understanding mission requirements, use of Analytical Hierarchy Process in configuration selection (2 Lec.) (1 Lab.); 3. Concept selection methodology: collection of statistical data, Pughs method, key performance indices, life cycle costs (2 Lec.) (1 Lab.); 4. Generating design alternatives: preliminary sizing using Tischenkos Method, preliminary weight estimation, rotor propulsive efficiency, Lift/Drag ratio, engine performance, main rotor blade weight estimation, rotor hub and swash plate (3 Lec.) (1 Lab.); 5. Performance: power required for hover, climb, level flight, maximum level speed, speed forbest endurance, best range, autorotative performance (3 Lec.) (2 Lab.); 6. Main rotor configuration design: rotor structural and aerodynamic design (number of blades, rotor diameter, blade chord, rotor inertia, blade twist, blade taper, blade tip shape, sweep, root cutout, tip speed, hinge offset, air foils, frequency placement, material selection) (5 Lec.) (3 Lab.); 7. Rotor component design: hub design, control power, helicopter stability considerations (3 Lec.) (2 Lab.); 8. Tail rotor/ antitorque systems: diameter, tip speed, disk area, number of blades, pusher vstractor (2 Lec.) (1 Lab.); 9. Fuselage and landing gear design (4 Lec.) (2 Lab.); 10. Vibration sources, vibration reduction (2 Lec.) (1 Lab.); 11. Life cycle cost estimation: environmental cost, purchase cost. operating cost (2 Lec.) (1 Lab.); 12. Leishman, J. G., Principles of Helicopter Aerodynamics, Cambridge Aerospace Series,2000. **Course Reference**: 1. Prouty, R. W., Helicopter Performance, Stability, and Control, Krieger Publishing Company, Florida, 1986; 2. Stepniewski, W. Z., and Keys, C. N., Rotary Wing Aerodynamics, Dover, New York,1984; 3. Venkatesan, CLecture Notes on Helicopter Technology; Department of Aerospace Engineering, liT Kanpur, 2000; 4. Filippone, A., Flight Performance of Fixed and Rotary Wing Aircraft, AIAA Education Series, 2006.
AE660A	PRELIMINARY DESIGN OF HELICOPTER	2-0-3-0-9	1. Introduction to: design process, design goals, types of rotorcraft (2 Lec.); 2. Understanding mission requirements, use of Analytical Hierarchy Process in configuration selection (2 Lec.) (1 Lab.); 3. Concept selection methodology: collection of statistical data, Pugh’s method, key performance indices, life cycle costs (2 Lec.) (1 Lab.); 4. Generating design alternatives: preliminary sizing using Tischenko’s Method, preliminary weight estimation, rotor

			propulsive efficiency, Lift/Drag ratio, engine performance, main ro tor blade weight estimation, rotor hub and swash plate (3 Lec.) (1 Lab.); 5. Performance: power required for hover, climb, level flight, maximum level speed, speed forbest endurance, best range, autorotative performance (3 Lec.) (2 Lab.); 6. Main rotor configuration design: rotor structural and aerodynamic design (number of blades, rotor diameter, blade chord, rotor inertia, blade twist, blade taper, blade tip shape, sweep, root cutout, tip speed, hinge offset, air foils, frequency placement, material selection) (5 Lec.) (3 Lab.); 7. Rotor component design: hub design, control power, helicopter stability considerations (3 Lec.) (2 Lab.); 8. Tail rotor/ antitorque systems: diameter, tip speed, disk area, number of blades, pusher vstractor (2 Lec.) (1 Lab.); 9. Fuselage and landing gear design (4 Lec.) (2 Lab.); 10. Vibration sources, vibration reduction (2 Lec.) (1 Lab.); 11. Life cycle cost estimation: environmental cost, purchase cost. operating cost (2 Lec.) (1 Lab.) **Course Reference :** 1. Leishman, J. G., Principles of Helicopter Aerodynamics, Cambridge Aerospace Series,2000; 2. Prouty, R. W., Helicopter Performance, Stability, and Control, Krieger Publishing Company, Florida, 1986; 3. Stepniewski, W. Z., and Keys, C. N., Rotary Wing Aerodynamics, Dover, New York,1984; 4. Venkatesan, C.,;Lecture Notes on Helicopter Technology; Department of Aerospace Engineering, liT Kanpur, 2000; 5. Filippone, A., Flight Performance of Fixed and Rotary Wing Aircraft, AIAA Education Series, 2006.
AE662	ROCKET ENGINE DESIGN	2-0-3--4	Introduction to rocket propulsion, Types of rocket engines, Elements of combustion, Chemical propellants and their burning characteristics, Aero thermodynamic design analysis of solid propellant rocket engine, Liquid propellant rocket engine, Design ofthrust chamber, Design of cooling system; Design of rocket Nozzle. **Course Reference**: 1. Sutton G.P and Ross D. M.; Rocket Propulsion Elements;, John Wiley & Sons,New York, 1985; 2. Barrere M, Jaumotte A and Vandenkerckhove 1; Rocket Propulsion, Elsevier Publishing Company, New York, 1960; 3. Hill, P.G. and Peterson C.R.,; Mechanics and Thennodynamics of Propulsion Addison Wesiey Publishing Company, 1965; 4. Oater G.C, ; Aero-thermodynamics of Gas Turbine and Rocket Propulsion, 3rdEdition, AIAA education Seria, 1998; 5. Mishra D.P.; Fundamental of Combustion Prentice Hall ofIndia, New Delhi; 6. Kuo K. K. and Summerfield,; Fundamentals Of Solid Propellant, combustion;progress in Astronautics and Aeronautics, Vol. 90, AIAA New York.
AE662A	ROCKET ENGINE DESIGN	2-0-3-0-9	Introduction to rocket propulsion, Types of rocket engines, Elements of combustion, Chemical propellants and their burning characteristics, Aerothermodynamic design analysis of solid propellant rocket engine, Liquid propellant rocket engine, Design ofthrust chamber, Design of cooling system; Design of rocket Nozzle.

AE663A	FUNDAMENTALS OF COMBUSTION	3-0-0-0-9	Introduction, Combustion and Thermochemistry: Motivation and objective, Property relations, Thermodynamic laws, Reactant & Product mixtures, Adiabatic flame temperature, Chemical equilibrium and equilibrium products Kinetics and Mechanism: Introduction, Global versus elementary reactions, Rates of reaction for multistep mechanisms Conservation equations: Simplified governing equations, Momentum, energy, mass conservation, Multi component diffusion, Concept of conserved scalar Laminar Premixed and Non premixed flames: Physical description, Simplified and detailed analysis, Flame speed, thickness, quenching, flammability limits, Flame stabilization, Nonremixed flames, laminar jets, Droplet Combustion, Solid fuel Combustion
AE670	AEROSPACE STRUCTURAL ANALYSIS - I	3-0-0-0-4	Free body diagram, equilibrium equations, examples from three-dimensional truss problems; bending moment, shear force. Introduction to theory of elasticity, stress, strain, stress strain relations, constitutive relations, basic equations of elasticity. Bending of beams, symmetrical and unsymmetrical sections, temperature effects, nonhomogeneous materials, modulus weighted sectional properties, thin walled sections. Deflection of beams. Torsion of circular and noncircular sections, thin walled sections, single and multiple closed cell sections. Shear in thin walled sections, shear center, single and multiple cell sections, combined bending and torsion. Plane strain and plane stress problems in elasticity. Eulers bucklingof columns.
AE670A	AEROSPACE STRUCTURAL ANALYSIS - I	3-0-0-0-9	Free body diagram, equilibrium equations, examples from three-dimensional truss problems; bending moment, shear force. Introduction to theory of elasticity, stress, strain, stress strain relations, constitutive relations, basic equations of elasticity. Bending of beams, symmetrical and unsymmetrical sections, temperature effects, nonhomogeneous materials, modulus weighted sectional properties, thin walled sections. Deflection of beams. Torsion of circular and noncircular sections, thin walled sections, single and multiple closed cell sections. Shear in thin walled sections, shear center, single and multiple cell sections, combined bending andtorsion. Plane strain and plane stress problems in elasticity. Eulers buckling of columns.
AE672	SOLID MECHANICS	3-0-0--4	Introduction. Material behaviour of idealized bodies, mathematical preliminaries, tensor analysis, partial derivatives, etc. Analysis of stress and strain measures. Laws of conservation, eqn. of motion, conservation of energy. Thermodynamic and mechanical equilibrium. Constitutive laws: viscoelastic materials.
AE672A	SOLID MECHANICS	3-0-0-0-9	Introduction. Material behaviour of idealized bodies, mathematical preliminaries, tensor analysis, partial derivatives, etc. Analysis of stress and strain measures. Laws of conservation, eqn. of motion, conservation of energy. Thermodynamic and mechanical equilibrium. Constitutive laws: visco-elastic materials.

AE673	ROCKET AND MISSILE STRUCTURES	3-0-0--4	Mission analysis, design approaches, analytical techniques, rocket grain analysis, structural types and optimization, honeycomb and sandwich construction, structural materials, aeroelasticity of cylindrical and conical shells, re-entry problems, ablation analysis, design examples, future trends, inflatable and expandable structure.
AE673A	ROCKET AND MISSILE STRUCTURES	3-0-0-0-9	Mission analysis, design approaches, analytical techniques, rocket grain analysis, structural types and optimization, honeycomb and sandwich construction, structural materials, aeroelasticity of cylindrical and conical shells, re-entry problems, ablation analysis, design examples, future trends, inflatable and expandable structure.
AE675	INTRODUCTION TO FINITE ELEMENT METHODS	3-0-0--4	Discussion on mathematical models, reliability of computer aided engineering analysis. Model problem of linear elastostatics in one dimension, principle of minimum potential energy, beam bending problem. Finite element discretisation in one dimension. One dimensional h/p code, Finite Element Formulation and development of two-dimensional code. Convergence analysis in two dimensions. Characterizational of solution smoothness, rate of convergence in energy norm, a posteriori error estimation. Direct computation of stresses and strains, postprocessing, superconvergent extraction techniques, nonlinear and time dependent problems.
AE675A	INTRODUCTION TO FINITE ELEMENT METHODS	3-0-0-0-9	Discussion on mathematical models, reliability of computer aided engineering analysis. Model problem of linear elastostatics in one dimension, principle of minimum potential energy, beam bending problem. Finite element discretisation in one dimension. One dimensional h/p code, Finite Element Formulation and development of two-dimensional code. Convergence analysis in two dimensions. Characterizational of solution smoothness, rate of convergence in energy norm, a posteriori error estimation. Direct computation of stresses and strains, post processing, superconvergent extraction techniques, nonlinear and time dependent problems.
AE676	AEROELASTICITY	3-0-0--4	Influence coefficients and function. Formulation of static and dynamic aeroelastic equations. Static aeroelasticity; divergence, aileron reversal & control effectiveness, solutions by matrix and energy methods. Unsteady aerodynamics, oscillating airfoil in incompressible flow, experimental methods, Dynamic aeroelasticity, flutter calculation, panel flutter.
AE676A	AEROELASTICITY	3-0-0-0-9	Influence coefficients and function. Formulation of static and dynamic aeroelastic equations. Static aeroelasticity; divergence, aileron reversal & control effectiveness, solutions by matrix and energy methods. Unsteady aerodynamics, oscillating airfoil in incompressible flow, experimental methods, Dynamic aeroelasticity, flutter calculation, panel flutter.
AE678	THEORY OF VIBRATIONS	3-0-0--4	Introd. Hamilton’s principles, Lagranges eqn, Eigenvalue problem (EVP), discrete& continuous system. Boundary value problem formulation. General EVP, positive definite

			system, self adjoint property. Vibration of strings, rods, beams, membranes and plates. Rayleighs quotient. Integral formulation of EVP, natural modes of vibration, approximate methods. Response to excitation.
AE678A	THEORY OF VIBRATIONS	3-0-0-0-9	Introd. Hamiltons principles, Lagranges eqn, Eigenvalue problem (EVP), discrete& continuous system. Boundary value problem formulation. General EVP, positive definite system, self adjoint property. Vibration of strings, rods, beams, membranes and plates. Rayleighs quotient. Integral formulation of EVP, natura modes of vibration, approximate methods. Response to excitation.
AE681	COMPOSITE MATERIALS	3-0-0--4	Introduction, Definition, classification, behaviors of unidirectional composites: prediction of strength, stiffness, factors influencing strength & stiffness, failure modes, analysis of lamina; constitutive classical laminate theory, thermal stresses. Design consideration, analysis of laminates after initial failure, interlaminar stresses, fracture mechanics, joints, experimental characterization. Performance under adverse environment.
AE681A	COMPOSITE MATERIALS	3-0-0-0-9	Introduction, Definition, classification, behaviors of unidirectional composites: prediction of strength, stiffness, factors influencing strength and stiffness, failure modes, analysis of lamina; constitutive classical laminate theory, thermal stresses. Design consideration, analysis of laminates after initial failure, interlaminar stresses, fracture mechanics, joints, experimental characterization. Performance under adverse environment.
AE683	RANDOM VIBRATIONS	3-0-0--4	Introduction to probability theory, random process. Excitation response relations forstationary random processes single and multidegree of freedom system with linear and nonlinear characteristics, continuous systems. Failure due to random vibration, application to aero, civil & mechanical systems.
AE683A	RANDOM VIBRATIONS	3-0-0-0-9	Intro. to probability theory, random process. Excitation response relations for stationary random processes single and multidegree of freedom system with linear and nonlinear characteristics, continuous systems. Failure due to random vibration, application to aero, civil & mechanical systems.
AE684	AIRCRAFT MATERIALS AND PROCESSES	3-0-0--4	Definition of various terms used for classification of materials. Mechanical properties. Testing of aircraft materials. Classification of alloys of aluminium, steel, titanium etc. High temperature problems; aerodynamic heating, design considerations, ceramic coating etc. Plastics, fibre reinforced composites, transparent materials.
AE684A	AIRCRAFT MATERIALS AND PROCESSES	3-0-0-0-9	Definition of various terms used for classification of materials. Mechanical properties. Testing of aircraft materials. Classification of alloys of aluminium, steel, titanium etc. High temperature problems; aerodynamic heating, design considerations, ceramic coating etc. Plastics, fibre reinforced composites, transparent materials.
AE685	DETERMINISTIC &	3-0-0--4	Free and forced vibration of discrete multidegree of freedom

	RANDOM VIBRATION		systems with and without viscous damping; impulse and frequency response methods. Continuous systems; natural modes, free & forced vibration. Random vibrations: intro. To probability theory, random variables & processes, properties of random processes, response of system to random excitations
AE685A	DETERMINISTIC & RANDOM VIBRATION	3-0-0-0-9	Free and forced vibration of discrete multidegree of freedom systems with and without viscous damping; impulse and frequency response methods. Continuous systems; natural modes, free & forced vibration. Random vibrations: intro. To probability theory, random variables & processes, properties of random processes, response of system to random excitations
AE686	HELICOPTER THEORY: DYNAMICS AND AEROELASTICITY	3----4	Historical development, configurations of helicopters, rotor system, flight control mechanism, momentum theory and blade element theory in hover, vertical flight and forward flight. Idealization of rotor blades, Flaplag and torsional dynamics of the blade. Trim and equilibrium analysis, aeroelastic stability of rotor blades. Flappitch, lagpitch and flaplag coupling, simple model of rotor fuselage dynamics, longitudinal and lateral stability and control of helicopters.
AE686A	HELICOPTER THEORY: DYNAMICS AND AEROELASTICITY	3-0-0-0-9	Historical development, configurations of helicopters, rotor system, flight control mechanism, momentum theory and blade element theory in hover, vertical flight and forward flight. Idealization of rotor blades, Flaplag and torsional dynamics of the blade. Trim and equilibrium analysis, aeroelastic stability of rotor blades. Flappitch, lagpitch and flaplag coupling, simple model of rotor fuse lage dynamics, longitudinal and lateral stability and control of helicopters.
AE687	AEROSPACE STRUC ANALYSIS II	3-0-0--4	General loads on aircraft, load factor, Vn diagram, effect of gust loading. Energy principles, potential and complementary potential; deflection analysis, indeterminate structures. Analysis of plates, Kirchhoff and first order shear deformation plate theories, buckling of plates, buckling of stiffened plates, local buckling of composite shapes.
AE687A	AEROSPACE STRUC ANALYSIS II	3-0-0-0-9	General loads on aircraft, load factor, Vn diagram, effect of gust loading. Energy principles, potential and complementary potential; deflection analysis, indeterminate structures. Analysis of plates, Kirchhoff and first order shear deformation plate theories, buckling of plates, buckling of stiffened plates, local buckling of composite shapes.
AE688	DYNAMICS AND VIBRATION	3-0-0--4	Rigid body dynamics: Newtons second law, impulse and momentum, moment of a force and angular momentum, work and energy, system of particles, rigid bodies, Eulers equations. Analytical mechanics: degrees of freedom, generalized coordinates, virtual work, Hamiltons principle, Lagranges equations. Linear system theory: frequency response, transform methods, transfer function, transition matrix, Eigen value problem, Modal analysis. Lumped parameter systems: single degree of freedom system, two degrees of freedom system, multiple degrees of freedom system. Continuous system: introduction, longitudinal, transverse and torsional vibrations of slender members.

AE688A	DYNAMICS AND VIBRATION	3-0-0-0-9	Rigid body dynamics: Newtons second law, impulse and momentum, moment of a force and angular momentum, work and energy, system of particles, rigidbodies, Eulers equations. Analytical mechanics: degrees of freedom, generalized coordinates, virtual work, Hamiltons principle, Lagranges equations. Linear system theory: frequency response, transform methods, transfer function, transition matrix, Eigen value problem, Modal analysis. Lumped parameter systems: single degree of freedom system, two degrees of freedom system, multiple degrees of freedom system. Continuous system: introduction, longitudinal, transverse and torsional vibrations of slender members.
AE689	INTRODUCTION TO THE THEORY OF SMART STRUCTURES	3-0-0-0-4	Introduction to smart materials, piezo, pyro and ferro electric effects; hysteresis effects: electric field in solids: fundamentals of continuum mechanics; basic conservation laws; thermodynamic principles; constitutive modelling for smart materials; electrothermoelastic formulation and analysis of smart structures; control of smart structures; applications to aerospace vehicles.
AE689A	INTRODUCTION TO THE THEORY OF SMART STRUCTURES	3-0-0-0-9	Introduction to smart materials, piezo, pyro and ferro electric effects; hysteresis effects: electric field in solids: fundamentals of continuum mechanics; basic conservation laws; thermodynamic principles; constitutive modelling for smart materials; electrothermoelastic formulation and analysis of smart structures; control of smart structures; applications to aerospace vehicles.
AE690	HIGH TEMPERATURE GAS DYNAMICS	3-0-0--4	Nature of high temperature flows, perfect and real gas, Gibbs free energy and entropy production, microscopic description of gases, thermodynamic properties, equilibirum properties kinetic theory, inviscid high temp. equilibrium and nonequilibrium flow, transport properties
AE690A	HIGH TEMPERATURE GAS DYNAMICS	3-0-0-0-9	Nature of high temperature flows, perfect and real gas, Gibbs free energy and entropy production, microscopic description of gases, thermodynamic properties, equilibirum properties kinetic theory, inviscid high temp. equilibrium and nonequilibrium flow, transport properties
AE692	MECHANICS OF HIGHLY DEFORMABLE STRUCTURES	3-0-0-0-4	Definition of large deformation of structures as large deflection, large rotation with small strains. Linear and nonlinear structural responses. Theory of elastica with exact and numerical solutions. Elements of large deformation mechanics: Reference and deformed configurations, Lagrange strain, Cauchy and Piola Kirchoff stress, work conjugate stress and strain measures. Governing equations in strong and weak form. Hyperelastic material constitutive law. Incremental numerical solution of large deformation boundary value problems: tangent stiffness, explicit and implicit methods, Newton Raphson method. Elastic and geometric stiffness. Total Lagrangian method. Corotational scheme. **Course Reference**: 1. JamesF. Doyle. Nonlinear analysis of thin walled structures. Springer Verlag. 2001; 2. M. A. Crisfield. Nonlinear finite element analysis of solids and structures. Vols. I and II. JohnWiley& Sons. 1991; 3. M.A.

			Biot. Mechanics of incremental deformations. John Wiley& Sons. 1965. 25-JUL-2013
AE692A	MECHANICS OF HIGHLY DEFORMABLE STRUCTURES	3-0-0-0-9	Definition of large deformation of structures as large deflection, large rotation with small strains. Linear and nonlinear structural responses. Theory of elastica with exact and numerical solutions. Elements of large deformation mechanics: Reference and deformed configurations, Lagrange strain, Cauchy and Piola Kirchoff stress, work conjugate stress and strain measures. Governing equations in strong and weak form. Hyper elastic material constitutive law. Incremental numerical solution of large deformation boundary value problems: tangent stiffness, explicit and implicit methods, Newton Raphson method. Elastic and geometric stiffness. Total Lagrangian method. Corotational scheme. **Course Reference:** 1. JamesF. Doyle. Nonlinear analysis of thin walled structures. Springer Verlag. 2001; 2. M. A. Crisfield. Nonlinear finite element analysis of solids and structures. Vols. I and II. JohnWiley & Sons. 1991; 3. M.A. Biot. Mechanics of incremental deformations. John Wiley& Sons. 1965.
AE694A	ACOUSTICS IN FLUIDS	3-0-0-0-9	Introduction to the course. Fundamentals of acoustics: Derivation of wave equation, speed of sound, harmonic waves, acoustic energy/intensity, decibel scale, acoustic impedance, reflection and transmission at the interface of two media. Wave propagation: Rectangular and circular ducts, cutoff frequency, free field propagation. Acoustics of resonantors: Travelling and standing waves, boundary conditions, eigen frequency and eigenmodes, effects of area variation, reflection and transmission of waves in pipes. Acoustic sources: Inhomogeneous wave equation, acoustic sources: monopole, bipole & quadrupole sources, acoustic reciprocity, aeroacoustic analogies. Attention of sound: Viscous and thermal conduction losses, absorption coefficient, sound absorption in pipes. Application of principles of acoustics: Aeroacoustic jet noise, combustion instability noise. **Course Reference**: 1. Lawrence E. Kinsler, Austin R. Frey, and Alan B. Coppens, 2000. Fundamentaals of acoustics, 4th edn. JohnWiley & Sons, Inc. 2. Philip M. Morse and K. Uno Ingard, 1986. Fundamentals of acoustics. 1st edn. Priceton University Press. 3. S.W. Rienstra & A. Hirschberg, 2000. An introduction to acoustics. http://www.win.tue.nl/sjoerder/papers/boek.pdf4. S.W. Rienstra & A. Hirschberg, 2004. An introduction to aeroacoustics. http://www.win.tue.nl/sjoerder/papers/lesswrmh.pdf 24-MAR-15
AE696	INSTRUMENTATION, MEASUREMENTS AND EXPERIMENTS IN FLUIDS	3----4	Need and objective, fundamentals of fluid mechanics, wind tunnels, visualization, HWA, pressure and noise measurements, temperature, wall shear stress, flow measurements, geophysical flows, spin up and spin down, data acquisition and processing, uncertainty analysis.

AE696A	INSTRUMENTATION, MEASUREMENTS AND EXPERIMENTS IN FLUIDS	3-0-0-0-9	Need and objective, fundamentals of fluid mechanics, wind tunnels, visualization, HWA, pressure and noise measurements, temperature, wall shear stress, flow measurements, geophysical flows, spin up and spin down, data acquisition and processing, uncertainty analysis.
AE698	INTRO TO VIRTUAL INSTRUMENTATION	2-0-3-0-4	Introduction to VI, typical applications, functional systems, graphical programming, data flow techniques, advantages of VI techniques. VI programming techniques; VIs and subVIs, loops and charts, arrays, clusters and graphs, case and sequence structures, formula nodes, string and file I/O, DAQ methods, code interfacenodes and DLL links. Sensors, transducers and signal conditioning; common transducers for displacement, temperature, load, pressure, flow etc. Single ended, floating and differential inputs, grounding, noise and filtering. Data acquisition basics; AD DAC, DIO, counters and timers, PC Hardware structure, timing, interrupts, DMA, operating system, PCI buses. Bus based instrumentation; instrumentation buses, GPIB, RS232C.
AE698A	INTRO TO VIRTUAL INSTRUMENTATION	2-0-3-0-9	Introduction to VI, typical applications, functional systems, graphical programming, data flow techniques, advantages of VI techniques. VI programming techniques; VIs and subVIs, loops and charts, arrays, clusters and graphs, case and sequencestructures, formula nodes, string and file I/O, DAQ methods, code interfacenodes and DLL links. Sensors, transducers and signal conditioning; common transducers for displacement, temperature, load, pressure, flow etc. Singleended, floating and differential inputs, grounding, noise and filtering. Dataacquisition basics; AD DAC, DIO, counters and timers, PC Hardware structure, timing, interrupts, DMA, operating system, PCI buses. Bus based instrumentation; instrumentation buses, GPIB, RS232C.
AE699	M TECH THESIS	0-0-0-0-0	Units: As arranged
AE699.	M TECH THESIS (FOR DUAL DEGREE ONLY)	0-0-0--9	M TECH THESIS (FOR DUAL DEGREE ONLY)
AE701	NONLINEAR FINITE ELEMENT METHOD	3-0-0--4	Overview of nonlinear problems in structural analysis geometric and material nonlinearities, nonlinear forces and boundary conditions; nature of forced eflectioncurves, critical points. Single degree of freedom system withgeometric nonlinearity Incremental solution, iterative solution using directand Newton Raphson approaches; combined incremental and iterative solution with full or modified Newton Raphson or initial stress method. One dimensional continuum problem: Axial bar under compression, variousstrain measures, weak and variational formulations based on Green strain measure. I D Finite element formulation: Total and Updated Lagrangian approaches: derivation of stiffness and tangent stiffness matrices, limitpoint and bifurcation; traversal of critical points. Two dimensional problems: Strain measures in two and three dimensions, stress measures (Cauchyand Piola Kirchhoff), objectivity, Updated Lagrangian formulation

			stress increments. 2D Incremental formulation with updates, derivation ofstiffness and tangent stiffness matrices. Advanced Solution Procedures: Line search, arc length quasi Newton and Secant methods. Nonlinear Dynamics: Direct Integration techniques: explicit and implicit solution techniques. Stability of time integration schemes. Newmarks scheme. The method; energy conserving and automatic time stepping methods. (1) Nonlinear finite element analysis of solids and structures, Vols. I and II, M.A. Crisfield, John Wiley and Sons (1994).(2) Finite Element Procedures, K.J. Bathe, Prentice Hall (1996).(3) Suggested journal papers
AE701A	NONLINEAR FINITE ELEMENT METHOD	3-0-0-0-9	Overview of nonlinear problems in structural analysis geometric and material nonlinearities, nonlinear forces and boundary conditions; nature of forced eflection curves, critical points. Single degree of freedom system with geometric nonlinearity Incremental solution, iterative solution using directand Newton Raphson approaches; combined incremental and iterative solution with full or modified Newton Raphson or initial stress method. One dimensional continuum problem: Axial bar under compression, variousstrain measures, weak and variational formulations based on Green strainmeasure. l D Finite element formulation: Total and Updated Lagrangian approaches: derivation of stiffness and tangent stiffness matrices, limitpoint and bifurcation; traversal of critical points. Two dimensional problems: Strain measures in two and three dimensions, stress measures (Cauchy and Piola Kirchhoff), objectivity, Updated Lagrangian formulation stress increments. 2D Incremental formulation with updates, derivation ofstiffness and tangent stiffness matrices. Advanced Solution Procedures: Line search, arc length quasi Newton and Secant methods. NonlinearDynamics: Direct Integration techniques: explicit and implicit solutiontechniques. Stability of time integration schemes. Newmarks scheme. The method; energy conserving and automatic time stepping methods. **Course Reference:** 1. Nonlinear finite element analysis of solids and structures, Vols. I and II, M.A. Crisfield, John Wiley and Sons (1994); 2. Finite Element Procedures, K.J. Bathe, Prentice Hall (1996); 3. Suggested journal papers
AE747	MOLECULAR GAS DYNAMICS	3-0-0-0-4	The molecular model; binary elastic collisions: basic kinetic theory; reference states & boundary conditions; collisionless flow; transition regime flows. Directsimulation Monte Carlo method. One dimensional flow of a simple monatomicgas. Measurements in low density flows.
AE747A	MOLECULAR GAS DYNAMICS	3-0-0-0-9	The molecular model; binary elastic collisions: basic kinetic theory; reference states and boundary conditions; collisionless flow; transition regime flows. Direct simulation Monte Carlo method. One dimensional flows of a simple monatomic gas. Measurements in low density flows.
AE751	FUNDAMENTALS OF LIQUID ATOMIZATION	3-0-0-0-4	Introduction to atomization, Physical processes in atomization, Types of atomizers, Classical Theories of

			atomization, Numerical modeling of atomization process, Theory of multiphase flows, Atomizer design: Single Fluid and Twin Fluid, SprayCharacterization Measurement techniques in Spray Characterization, Applications of Atomizers Metal forming Chemical Industry Combustion.
AE751A	FUNDAMENTALS OF LIQUID ATOMIZATION	3-0-0-0-9	Course Details: Introduction to atomization, Physical processes in atomization, Types of atomizers, Classical Theories of atomization, Numerical modeling of atomization process, Theory of multiphase flows, Atomizer design: Single Fluid and Twin Fluid, Spray Characterization Measurement techniques in Spray Characterization, Applications of Atomizers Metal forming Chemical Industry Combustion.
AE752	PRINCIPLES OF ACOUSTICSV	3-0-0-4-4	Wave theory of sound: Plane waves, Harmonic waves and complex Algebra, Speed ofsound, Energy, Intensity and Power, Spherical wavesb. Quantitative measurement of sound: Frequency content and bands, Decibel scale, Multiple frequency signals, coherence, Frequency domain representation of transientsignalsc. Propagation of Plane waves: Reflection from a rigid surface, Propagation in a tube, Radiation due to waves on the wall, Oblique reflection and transmission at a planar interfaced. Radiation from Vibrating Bodies: Oscillating spheres, Monopoles and Multipoles.
AE752A	PRINCIPLES OF ACOUSTICSV	3-0-0-0-9	Wave theory of sound: Plane waves, Harmonic waves and complex Algebra, Speed ofsound, Energy, Intensity and Power, Spherical wavesb. Quantitative measurement of sound: Frequency content and bands, Decibel scale, Multiple frequency signals, coherence, Frequency domain representation of transient signals. Propagation of Plane waves: Reflection from a rigid surface, Propagation in a tube, Radiation due to waves on the wall, Oblique reflection and transmission at a planarinterfaced. Radiation from Vibrating Bodies: Oscillating spheres, Monopoles and Multipoles.
AE753	THEORY OF COMBUSTION	3-0-0-0-4	Introduction to combustion: Types of flames, role of chemical kinetics Chemical Kinetics: Formulation of chemical kinetics equations, reaction mechanisms, steady state approximation, Arrhenius Law: Formulation of Arrhenius law, Microscopic consideration of reaction rates. Explosions: Thermal explosions, Chain branching explosions, Chemical equilibrium Conservation equations for reacting flows: Shvab Zeldovich formulation. Laminar premixed combustion: Flame speed Thermal theory (Mallard and Le Chatellier), DiffusionTheory (Zeldovich, Frank Kamenstakii and Semenov), Flame stabilization, Quenching and Flammability limits micro combustion. Detonation and Deflagration: Chapman Hugoniot relations, Chapman Jouguet points Liminarnon premixed conbustion: Burke Schuman Analysis, Phenomenological Analysis Ignition, Extinction and Flammability. Turbulet premixed combustion: Theories, Time and length scales, thin flame approach, stirred reactor. Turbulent nonpremixed

			combustion: Conserved scalar approach, two variable approach, flamelet model, direct closure.
AE753A	THEORY OF COMBUSTION	3-0-0-0-9	Introduction to combustion: Types of flames, role of chemical kinetics Chemical Kinetics: Formulation of chemical kinetics equations, reactionmechanisms, steady state approximation, Arrhenius Law: Formulation of Arrhenius law, Microscopic consideration of reaction rates. Explosions: Thermal explosions, Chain branching explosions, Chemical equilibrium Conservation equations for reacting flows: Shvab Zeldovich formulation. Laminar premixed combustion Flame speed Thermal theory (Mallard and Le Chatellier), Diffusion Theory (Zeldovich, Frank Kamenstakii and Semenov), Flame stabilization, Quenching and Flammability limits micro combustion. Detonation and Deflagration: Chapman Hugoniot relations, Chapman Jouguet points Liminarnon premixed conbustion: Burke Schuman Analysis, Phenomenological Analysis Ignition, Extinction and Flammability. Turbulet premixed combustion: Theories, Time and length scales, thin flame approach, stirred reactor. Turbulent nonpremixe combustion: Conserved scalar approach, two variable approach, flamelet model, direct closure.
AE754	TURBULENT COMBUSTION	3-0-0-0-4	Introduction, Governing equations, Statistical description of turbulence, Turbulent scales and correlations, Reynold saveraged equations, Mixing, Flows with premixed and nonpremixed reactants, Numerical and experimental methods for reacting flows. Introduction Motivation and objective Governing equationsTurbulence Introduction Turbulent scales Spatial and temporal correlations Reynold saveraged equations Wall bounded shear flows Free shear flows Statistical description. Turbulence modeling and Mixing Introduction Turbulence modeling Molecular mixing Turbulent mixing Reaction diffusion systemsFlows with premixed and nonpremixed reactants Introduction to premixed and nonpremixed mixtures Moment methods Wellstirred reactor Conserved scale methodsNumerical and experimental methods for Reacting flows Combustion CFD Numerical solvers for stiff differential equations General concepts about experimental methods Measurement techniques. **Course Reference**: 1. A first course in Turbulence, Tennekes and Lumley; 2. An introduction to combustion, Stephen Turns; 3. Turbulent Combustion, N. Peters; 4. Combustion Theory, F. Williams; 5. Theoretical and Numerical Combustion, Poinsot and Veynante
AE754A	TURBULENT COMBUSTION	3-0-0-0-9	Introduction, Governing equations, Statistical description of turbulence, Turbulent scales and correlations, Reynold saveraged equations, Mixing, Flows with premixed and nonpremixed reactants, Numerical and experimental methods for reacting flows. Introduction Motivation and objective Governing equationsTurbulence Introduction Turbulent scales Spatial and temporal correlations Reynold saveraged equations Wallbounded shear flows Free shear flows Statistical description. Turbulence modeling and

			Mixing Introduction Turbulence modeling Molecular mixing Turbulent mixing Reaction diffusion systems Flows with premixed and nonpremixed reactants Introduction to premixed and nonpremixed mixtures Moment methods Wellstirred reactor Conserved scale methods Numerical and experimental methods for Reacting flows Combustion CFD Numerical solvers for stiff differential equations General concepts about experimental methods Measurement techniques. **Course Reference**: 1. A first course in Turbulence, Tennekes and Lumley; 2. An introduction to combustion, Stephen Turns; 3. Turbulent Combustion, N. Peters; 4. Combustion Theory, F. Williams; 5. Theoretical and Numerical Combustion, Poinsot and Veynante
AE777	OPTIMAL SPACE FLIGHT CONTROL	3-0-0-0-4	1. Control Systems (Basic definitions, notation, tracking systems.); 2. Guidance and navigation (Basic concepts, linear regulation and tracking, proportional navigation, crossproduct steering); 3. Optimal control techniques (Multivariable optimization, constrained minimization, optimal control of dynamic systems, Hamiltonian and the minimum principle, HamiltonJacobi Bellman formulation, end point constraints, EulerLagrange formulation, two point boundary value solution techniques, optimal terminal control with interior constraints, singular control, neighbouring extremals, linear optimal control, stochastic systems, Kalman filtering, LQG/LTR and Hinfinity robust optimal control.) 4. Optimal guidance and control of rocket flight (Terminal guidance of interceptors, nonplanar tracking systems (3DPN), Goddards problem, 2PBVP solutions for gravityturn trajectories, attitude autopilots, pitch maneuver control of launch vehicles.) 5. Optimal spacecraft navigation and control (Introduction to orbital mechanics, Hill Clohessey Wiltshire model, autonomous rendezvous and docking, minimum energy transfer, Lamberts problem, optimal guidance of reentry vehicles, nonplanar orbital regulation, optimal threeaxis control by thrusters, reaction wheels and control moment gyros.) **Course Reference**: 1. Tewari, A., Advanced Control of Aircraft, Spacecraft, and Rockets, John Wiley &Sons, Chichester, 2011; 2. Tewari, A., Atmospheric and Space Flight Dynamics, Birkhuser, Boston, 2006; 3. Bryson, A.E., Jr., and Ho, Y.C., Applied Optimal Control. Hemisphere, 1975; 4. Athans, M., and Falb, P.L., Optimal Control. Dover, 2007.
AE777A	OPTIMAL SPACE FLIGHT CONTROL	3-0-0-0-9	1. Control Systems (Basic definitions, notation, tracking systems.); 2. Guidance and navigation (Basic concepts, linear regulation and tracking, proportional navigation, crossproduct steering); 3. Optimal control techniques (Multivariable optimization, constrained minimization, optimal control of dynamic systems, Hamiltonian and the minimum principle, Hamilton Jacobi Bellman formulation, endpoint constraints, EulerLagrange formulation, twopoint boundaryvalue solution techniques, optimal terminal control with interior constraints, singular control, neighbouring

			extremals, linear optimal control, stochastic systems, Kalman filtering, LQG/LTR and Hinfinity robust optimal control.); 4. Optimal guidance and control of rocket flight (Terminal guidance of interceptors, nonplanar tracking systems (3DPN),Goddards problem, 2PBVP solutions for gravityturn trajectories, attitude autopilots, pitch maneuver control of launch vehicles.); 5. Optimal spacecraft navigation and control (Introduction to orbital mechanics, Hill Clohessey Wiltshire model, autonomous rendezvous and docking, minimum energy transfer, Lamberts problem, optimal guidance of reentry vehicles, nonplanar orbital regulation, optimal threeaxis control by thrusters, reaction wheels and control moment gyros.) **Course Reference**: 1. Tewari, A., Advanced Control of Aircraft, Spacecraft, and Rockets, John Wiley &Sons, Chichester, 2011; 2. Tewari, A., Atmospheric and Space Flight Dynamics, Birkhuser, Boston, 2006; 3. Bryson, A.E., Jr., and Ho, Y.C., Applied Optimal Control. Hemisphere, 1975; 4. Athans, M., and Falb, P.L., Optimal Control. Dover, 2007.
ESO204	MECHANICS OF SOLIDS	3-1-0-1-4	Free body diagram with examples on modelling of typical supports and joints,Conditions for equilibrium in 3D and 2D, Friction: limiting and nonlimiting cases; Forcedisplacementrelationship and geometric compatibility (for small deformations) with illustrations through simpleproblems on axially loaded members and thinwalled pressure vessels; Concept of stress at a point,Plane stress case: transformation of stresses at a point, principal stresses and Mohr's circle, Displacement field, Concept of strain at a point, Plane strain case: transformation of strain at a point,principal strains and Mohr's circle, Strain Rosette; Discussion of experimental results on 1D material behaviour, Concepts of elasticity, plasticity, strainhardening, failure (fracture/yielding), Idealization of 1D stressstrain curve, Generalized Hooke's law (without and with thermal strains) for isotropic materials, Complete equations of elasticity; Force analysis (axial force, shear force, bending moment, and twisting moment diagrams) of slender members (singularity functions nat to be used); Torsion of circular shafts and thinwalled tubes (plastic analysis and rectangular shafts not to be discussed); Moment curvature relationship for pure bending of beams with symmetric crosssection, bending stress,shear stress (Shear centre and plastic analysis not to be discussed); Cases of combined stresses, Conceptof strain energy, Yield criteria; Deflection due to bending, Integration of the moment curvature relationship for simple boundary conditions, Method of superposition (singularity functions not to beused); Strain energy and complementary strain energy for simple structural elements (those under axialload, shear force, bending moment, and torsion), Castigliano theorems for deflection analysis and indeterminate problems; Concept of elastic instability, Introduction to column buckling, Euler formula(postbuckling behaviour not to be covered)

			Course Reference: 1. Crandall, S.H., Dahl, N.C., and Lardner, T. J., An Introduction to the Mechanics of Solids, McGrawHill,Second Ed. with 51 Units, 1978; 2. Beer, F.P, Johnston, E.R. and DeWolf, J.T., Mechanics of Materials, Tata McGrawHill Edition2004; 3. Meriam, J.L. and Kraige, L.G., Engineering Mechanics, Vol. 1: Statics, John Wiley,Second Ed. with 51 Units, 1980; 4. Popov, E.P., Engineering Mechanics of Solids, PrenticeHall, First Ed., 1990
ESO204A	FLUID MECHANICS AND RATE PROCESSES		FLUID MECHANICS: Introduction to fluids, Fluid statics; pressure as a scalar, manometry, forces on submerged surfaces (NO moments NOR center of pressure), Description of flows; field approach, Euler acceleration formula, streamlines, streaklines, etc., Reynolds transport theorem Conservation of mass; stream function, Linear (NOT angular) Momentum balance, Navier Stokes (NS) equation; elementary derivation; application; Poiseuille flow, Couette flow, Energy equation Bernoulli equation, applications including flow measurement (Pitot tube, Orifice meters); Pipe flows and losses in fittings; Similitude and modelling: using nondimensionalization of NS equations and boundary conditions, simplifications for cases without free surfaces and without cavitation (scale factor approach should NOT be done); High Re flow: Prandtls approximation; basic inviscid flow; need for boundary layer; Magnus effect (mathematical derivations be avoided), Boundary layerselementary results for flat plates. Separation, flow past immersed bodies (bluff, streamlined); physics of ballgames (qualitative) Heat Transfer: Introduction, rate law and conservation law, Conduction equation; nondimensionalization, various approximations, Steady state conductionconcept of resistances in series and of critical thickness of insulation, Unsteady conduction; significance of Biot and Fourier numbers, Heissler charts; Low Bi case;
SE371	FOUNDATION OF SCIENTIFIC COMPUTING	3-0-0--4	Basics of Computing: discretization and numerical errors. ODEs and their computations. Stiff ODEs & parasitic error, solving stiff equation via orthogonolization and compound matrix method. Governing PDEs for scientific computing and their classification. Wave mechanics: hyperbolic and dispersive waves. Dispersion relation and spacetime resolution. Finite difference methods for wave equation. Discretization of spatial derivatives by polynomial expansion and operator’s explicit methods. Spectral theory of discrete computing: stability analysis; Theory of signal and error propagation; dispersion relation preservation (DRP) property. Finite difference methods (FDM) for wave equation. Designing high accuracy, high fidelity methods via error control as an optimization problem. Spectral method visvis discrete computing methods: Aliasing error and focusing; Capturing discontinuities and Gibbs phenomenon; qwavesin computing. Numerical Methods for Partial Differential Equations WF Ames Fundamentals of Computational Fluid Dynamics: T. K. Sengupta.Waves in

			Fluids M. J. LighthillComputational Aeroacoustics: M. J. Lighthill.Linear and Nonlinear Waves: G. B. Whitham. 17-SEP-14
SE422	FOUNDATION OF SCIENTIFIC COMPUTING	3-0-0-0-3	Basics of Computing: discretization and numerical errors. ODEs and their computations. Stiff ODEs & parasitic error, solving stiff equation via orthogonolization and compound matrix method. Governing PDEs for scientific computing and their classification. Wave mechanics: hyperbolic and dispersive waves. Dispersion relation and spacetime resolution. Finite difference methods for wave equation. Discretization of spatial derivatives by polynomial expansion and operator’s explicit methods. Spectral theory of discrete computing: stability analysis; Theory of signal and error propagation; dispersion relation preservation (DRP) property. Finite difference methods (FDM) for wave equation. Designing high accuracy, high fidelity methods via error control as anoptimization problem. Spectral method visvis discrete computing methods: Aliasing error and focusing; Capturing discontinuities and Gibbs phenomenon; qwavesin computing. Numerical Methods for Partial Differential Equations WF AmesFundamentals of Computational Fluid Dynamics: **Course Reference**: 1. T. K. Sengupta.Waves in Fluids M. J. Lighthill; 2. Computational Aeroacoustics: M. J. Lighthill.Linear and Nonlinear Waves: G. B. Whitham. 17-SEP-14

BIOLOGICAL SCIENCE AND ENGINEERING

BIOLOGICAL SCIENCES AND BIO-ENGINEERING

BT								Template No. BSBE-1
	SEMESTER							
COURSES	1st	2nd	3rd	4th	5th	6th	7th	8th
	MTH101A [11]	MTH102A [11]	BSE211A [09]	BSE221A [09]	BSE311A [09]	BSE321A [10]	BSE411A [11]	BSE421A [11]
	PHY101A [03]	PHY103A [11]	ESC201A [14]	BSE222A [09]	BSE312A [09]	BSE322A [10]	BSE412A [09]	HSS-5 (Level-2) [09]
	PHY102A [11]	ESC101A [14]	TA201A [06]	BSE223A [09]	BSE301A [02]	OE-2 [09]	OE-4 [09]	DE-3 [09]
	LIF101A [06]	CHM101A [03]	ESO-1 [09] (ESO206A)	HSS-2 (Level-1) [11]	HSS-3 (Level-2) [09]	HSS-4 (Level-2) [09]	OE-5 [09]	DE-4 [09]
	ENG112A/HSS-1 (Level-1) [11]	CHM102A [08]	ESO-2 [~10]*	TA202A [06]	OE-1 [09]	OE-3 [09]	DE-2/UGP-3 [09] (BSE498A)	OE-6 [09]
	PE101A [03]	PE102A [03]	-	SO-1 [11] (MSO201A)	ESO-3 [~10]*	DE-1/UGP-2 [09] (BSE399A)	-	UGP-4 [09] (BSE499A) (Extra Credits)
	TA101A [09]	-		COM200A [05]	UGP-1 [04] (BSE398A) (Extra Credits)	-		-
	54	50	48*	60	48 – 52*	56	47	47/56

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	107	Credits
Department Elective (DE)	:	36	Credits
Open Elective (OE)	:	54	Credits
*SO/ ESO	:	40	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	410	Credits

REMARKS:

1) *ESO/SO courses are available in a range from 6 to 14 credits each. Students may choose any ESO/SO courses in open ESO/SO slots to ensure that their 4-course ESO/SO totals up to 40 credits.
2) DE credits may include 18 credits of UGP-2 and UGP-3.
3) UGP-1 and UGP-4 are optional and do not count towards DE/OE credits.
4) Upto 36 OE credits may be waived from the minimum requirements for students opting for either Dual Degree or Double Major programme.
5) For students opting for the BT/MT dual degree programme under category A, BSE498A and BSE499A are mandatory.

BT-MT (Category – A) *(from the same department)*						Template No. BSBE-2
	Mandatory UG Component		PG Component			
COURSES	Odd Semester	Even Semester	7th	8th	9th	10th
	BSE498A [09]	BSE499A [09]	DE PG-1 [09]	DE PG-3 [09]	BSE702A/BSE701A [0]	M.Tech. Thesis [36]
	-	-	DE PG-2 [09]	DE PG-4 [09]	M.Tech. Thesis [36]	-
			BSE601A [0]	BSE701A/BSE702A [0]	-	
			-	BSE602A [0]		
	09	09	18	18	36	36

MINIMUM CREDIT REQUIREMENT IN MT PART FOR GRADUATION:

PG Component	:	36	Credits
Thesis	:	72	Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ DUGC Convener.
2) For students opting for the BT/MT dual degree programme under category A, BSE498A and BSE499A are mandatory.
3) BSE701A and BSE702A (seminar courses) are mandatory.
4) BSE601A (Communications course) and BSE602A (Laboratory course) are mandatory.
5) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
6) Upto 36 OE credits may be used from the BT minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the BT programme and counted towards PG requirements.

BS/BT-MT (Category – B) *(from other departments)*					Template No. BSBE-3	
C	UG Pre-Requisites		PG Component			
O	Odd Semester	Even Semester	7th	8th	9th	10th
U	ESO206A [09]	BSE221A [09]	BSE611A [09]	DE PG [09]*	M.Tech. Thesis [36]	M.Tech. Thesis [36]
R	BSE211A [09]	-	BSE613A [09]	BSE701A/BSE702A [0]	BSE702A/BSE701A [0]	-
S	BSE311A [09]		BSE632A [09]	BSE602A [0]	-	
E			BSE633A [09]			
S			BSE601A [0]			
	27	09	36	09	36	36

MINIMUM CREDIT REQUIREMENT IN MT PART FOR GRADUATION:

PG Component : 45 Credits
Thesis : 72 Credits

Basket – A
BSE629A [09]
BSE630A [09]
BSE631A [09]
BSE636A [09]
BSE638A [09]

REMARKS:

1) *DE PG should be selected from Basket A
2) BSE701A and BSE702A (seminar courses) are mandatory
3) BSE601A (Communications course) and BSE602A (Laboratory course) are mandatory.
4) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
5) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the parent department's BT programme requirements and counted towards PG requirements.
6) All courses to be taken with the permission of Supervisor/ DUGC Convener.

DOUBLE MAJOR	Template No. BSBE-4
Odd Semester	Even Semester
Pre-Requisites	
ESO206A [09]	
Mandatory BSBE Courses	
BSE211A [09]	BSE221 [09]
BSE301A [02]	BSE222 [09]
BSE311A [09]	BSE223 [09]
BSE312A [09]	BSE321A [10]
BSE411A [11]	BSE322A [10]
BSE412A [11]	BSE421A [11]
51	58

TOTAL MANDATORY CREDITS FOR SECOND MAJOR IN BSBE: 109 CREDITS

REMARKS:

1) Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.

MINOR		Template No. BSBE-5
Title	TISSUE ENGINEERING	
C O	BSE211A [09]	
U	BSE411A [11]	
R	BSE421A [11]	
S E S	-	
	31	

DEPARTMENT OF BSBE			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
BSE100	INTRODUCTION TO BIOLOGICAL SCIENCES & BIOENGG.	1-0-0--0	Biology in the 21st Century The brave new world in the post genome era. Past, present and future of our society, industry and life style: impact of discoveries and technological innovations in biology. Challenges and excitement of researchin biology and bioengineering. Bioengineering as an emerging science at theintersection of biology, engineering, physics and chemistry. Career opportunitiesin biotechnology, biomedical engineering, pharmaceutical industry, agrobiotechnology and in the diverse areas of basic science and medical research. Emerging trends of collaboration between industry and academia for development of entrepreneurship in biotechnology, Lab tours.
BSE211A	ORGAN SYSTEM, PHYSIOLOGY AND ANATOMY	3-0-0-0-9	Animal Tissues & Organ Systems: Concept of self assembly, energy and evolution, Basic structure of the cell, Organization of the cells to from different tissue systems, Assembly of different tissue system to form organ system, Crosstalk of different organ system to form adynamic living system Homeostasis: Acid, Base, Salt, Concept of pH, Intracellular & extracellular fluid,Thermoregulation Transport Phenomenon: Energy dependent and energy independent transport of molecules ina system Nervous System: Organizational assembly of the nervous network in the body and its cross talk with different organ system Sensory System: Basic anatomy of the different sensory system of the body, Signal receptionfrom the outside environment by these different sensory modalities and relaying the information to the nervous system Endocrine System: Outline of the different endocrine system in the body and their functioning,Cross talk between endocrine and nervous system in carrying out physiological functions Circulatory System and Blood: Network of the blood vessel in the body and their fine structuralmodifications, Composition of the circulating fluid: Blood, Different between blood and plasma,Structure of the pumping station: the heart, Functioning of the heart, ECG recordings, Control system of the heart Immune System and Lymphatic System: Basic concept of immunity, Classification of immune system, Basic functioning of different components of immune system, Basic concept of lymphatic system, Crosstalk between immune system nervous system and endocrine system Muscoskeletal System: Anatomy of the muscoskeletal system, Tissue organization of thebone, cartilage and muscle, Role of

			the muscoskeletal system in movement Respiratory System: Structure of the lungs, Process of gas exchange (C02 and 02) in thelunQs to provide oxygen rich blood to the body Digestive System: Anatomy of the digestive system, Functioning of the individual orga Biology Eight Edition, N. A. Campbell & J. B. Reece (2008)
BSE212	MOLECULAR BIOLOGY	3-0-0--4	Genome as the store house of information, DNA as the carrier of encoded messages. Genomic diversity across organisms as a source of embedded intelligence in nature. Intracellular transmission of genetic messages and their cellular translation; Cellcell communication and feedback; Selective transmission of genetic messages regulation of gene expression; logic of building body plans developmental translation of encoded messages. Techniques of DNA manipulation and engineering.
BSE216	BIOCHEMISTRY	3-0-0--4	Properties of water, Acids, Bases and Buffers. First and Second law of thermodynamics; Free energy as an indicator of spontaneity; Chemical Equilibria. Amino Acids of Proteins; Optical Activity. Primary Structure Determination; Three Dimensional Structures of Proteins: Secondary Structure; Fibrous Proteins; Globular Proteins; Quaternary Structure. Polysaccharides; Glycoproteins. Lipidsand Membranes; Mechanisms of enzyme action; Substrate Specificity; Coenzymes; Regulation of Enzymatic Activity: enzyme kinetics, inhibition; effects of pH. Catalytic mechanisms, Biosynthesis of amino acids, lipids and nucleotides.
BSE221A	BIOCHEMISTRY	3-0-0-0-9	Enzymes: Concepts, kinetics, catalytic strategies and regulation: Free energy as athermodynamic function, formation of transition states, The Michaelis Menten model, enzyme inhibitors, coenzymes, proteases, oxygen transport, hemoglobin, allostery, isozymesMetabolism basic concepts and design: Introduction, coupled reactions and interconnectivities. Glycolysis and Gluconeogenesis: Energy conversion pathways in organisms, control of glycolytic pathway, synthesis of glucose from noncarbohydrate precursors, reciprocal regulation of gluconeogenesis and glycolysis. The citric acid Cycle: Pathway, control, source of biosynthetic precursors, glyoxylate cycle. Oxidative phosphorylation and electron transport chain: Mitochondrial membrane, electrontransfer, proton pumps and physical link to citric acid cycle, regulation of cellular machineryGlycogen metabolism: Interplay of enzymes, epinephrine and glucagon signaling, reciprocal regulation of glycogen breakdown and synthesis.Fatty acid Metabolism: Triacylglycerols as energy stores, stages of processing, pathways of synthesis and degradation, acetyl Coenzyme ASynthesis of the molecules of life : Nitrogen fixation, amino acid synthesis, feedback inhibition,pyrimidine and purine synthesis, salvage pathway, synthesis of lipids and steroids, regulationof cholesterol biosynthesisProtein Folding and turnover: Stability, pathways of folding, chaperones, proteasomes,

			aminoacid degradation, urea formation. **Course Reference**: 1. Biochemistry by Jermy M Berg, John L Tymoczko and Luber! Stryer, Publisher: W. H. Freeman; Seventh Edition (December 24, 201 0); 2. Principles of Biochemistry by Albert Lehninger, David L Nelson, Michael M Cox, Publisher: W. H.Freeman; Fifth Edition (June 15, 2008).
BSE222A	BIOCHEMICAL ENGINEERING		energetics of microbial metabolism; transport phenomena; enzyme catalyzed reactions andprocesses; bioreactor design and applications; sterilization; instrumentation and control. Bioseparations and Bioprocesses: Downstream processing; matrix design; pretreatment methods; separation of cell biomass; adsorption; filtration, precipitations; affinity precipitations; column chromatography; plate theory and principles of chromatography; different types of chromatography, polishing crystallization, drying, separation case studies; process integration; bioprocess integration for efficient production and recovery, scaleup consideration, process monitoring and process economics. Environmental Bioprocesses: Interaction of mixed microbial population; aerobic and anaerobic processes; applications; biological wastewater treatment, bioremediation. Enzyme Technology: Enzyme catalyzed reactions. Cell and Enzyme immobilization. Industrialapplications and case studies. **Course Reference**: 1. Blanch, H. W. and Clark, D. S; Biochemical Engineering. Marcel Dekker, Inc; 2. Bailey, J. E. and Ollis, D. F, Biochemical Engieering Fundamentals; McGrawHill, Inc.; 3. Belter, P. A., Cussler, E. L. and Hu, W. S. Bioseparations: Downstream Processing for Biotechnology; John Wiley & Sons; 4. Desai, Mohamed. A. Downstream Processing of Proteins: Methods and Protocols. Humana Press; 5. Shuler, M. L. and Kargi, F. Bioprocess Engineering Basic Concepts; 6. Amersham Biosciences literature notes on chromatography
BSE223A	BIOCHEMISTRY & BIOCHEMICAL ENGINEERING LAB	1-0-6-0-9	Fundamentals of Biochemistry: This section will deal with the experiments which can be used to determine the biomolecules both quantitatively and qualitatively. Experiment related to Spectrophotometry Beer Lambert Law. Experiment describing the preparation ofstandard plot for model protein such as bovine serum albumin (BSA). Quantifying theunknown protein using spectrophotometric measurements by UV adsorption, Lowrymethod, dye binding method, Bicinchoninic acid (BCA) method. Analysis of the presenceof glucose and quantifying the concentration using Dinitrosalicylic acid (DNSA) method. Enzyme activity, Enzyme kinetics, Starch conversion to glucose by salivary amylase. Paranitrophenyl. Dglucopyranoside (pNPG) assay for glucosidase. Analysis ofproteins by SDSPAGE. Biochemical Engineering Bioseparations and Bioprocesses: Experiments related to upstream processing and downstream processing. Fermentation

			and microbial massculture. Downstream processing; harvesting of cell mass and extraction of protein/enzyme (adsorption, filtration}, cell sonication, precipitation, column chromatography, column regeneration, affinity column preparation, purification, protein and enzyme activity measurements, SDSPAGE analysis, data compiling. Ethanol Fermentation. Bioreactor operation (25 Its), tangential/cross flow filtration for cell harvesting, computer simulation, mass transfer phenomenon and cell growth kinetics. **Course Reference**: 1. Introductory Practical Biochemistry by S. K. Sawhney and Randhir Singh, Publisher: Alpha ScienceInternational, Ltd (August 1, 2005); 2. Protein Purification Applications Practical Approach by Simon Roe Oxford University Press; 3. Bioprocess EngineeringBasic concepts by Michael L. Shuler and Fikret Kargi; 4. Practical notes issued in the lab
BSE292	BSBE LAB-I MOLECUTAR BIOLOGY	0-0-4--2	Use of Transgenic organisms in the study of gene expression methodology toobtain high affinity antibodies.
BSE301A	SCIENTIFIC & PROFESSIONAL COMMUNICATION	0-0-2-0-2	Essential elements of written communication: discussion of a topic, identification of the key elements, clarity of the rationale in a scientific and technical work, elaboration of technical details, key elements and highlights of a finding/project, identification of whatanswers have been obtained, what remains to be answered. How to underscore thesignificance of a project/finding, and its larger meaning, conclusions Essential elements of verbal communication: what communication skills interests audience, how to navigate through complex set of information, the art of displaying thekey messages, overcoming language barriers, translation of scientific message for thelay audience, making new ideas understandable, how to engage with the audience.
BSE311A	MOLECULAR CELL BIOLOGY	3-0-0-0-9	Molecular Genetic Techniques and Genomics: Genetic analyses of mutations to indentify and study genes; DNA cloning and characterization; Genome wide analyses of gene structure andgene expression; Inactivating the function of specific genes in eukaryotes; Identifying andlocating human disease genes Molecular Structure of Genes and Chromosomes: Chromosomal organization genes and non coding DNA; Mobile DNA; Structural organization of eukaryotic chromosomes; organelle DNAs Transcriptional Control of Gene Expression: Eukaryotic gene control and RNA polymerase; regulatory sequences in protein coding genes; activators and repressors of transcription;mechanism of transcription activation and repression. Post transcriptional Gene Control: Processing of eukaryotic prem RNA; transport across nuclear envelope; cytoplasmic mechanism of posttranscriptional control; processing of RNA and RNA, regulation of protein synthesis. Cell signalling: Signalling molecules and cell surface receptors; intracellular signal transduction; G protein coupled receptors. Membrane

			trafficking: Translocation of secretory proteins across the ER membrane; protein modifications, folding and quality control in the ER; export and sorting of proteins. Eukaryotic cell cycle: Biochemical and genetics studies on cell cycle; mechanisms regulating mitotic events; meiosis a special type of cell division. **Course Reference**: 1. Molecular Cell Biology, by Lodish et al (5th edition or recent), W.H. Freeman and Company, New York; 2. Molecular Biology of the Cell, by Alberts et al (4th edition or later), Garland Sciences, New York.
BSE312A	MOLECULAR BIOLOGY LAB	1-0-6-0-9	Microbiology: Introduction to sterilization techniques and certain equipment used for sterilization or maintenance of a sterile environment e.g. the autoclave and the laminar flow hood. Learning the basic principles of making solutions used for microbiological and molecular biological experiments, such as buffers, medium for microbial culture etc. Measurement of pH and introduction to the pH meter. Learning how to make liquid andsolid medium for microbial culture and the various techniques for growing microbial cultures in liquid and solid medium. Learning the principles and application of a basic staining technique to identify bacterial subtypes e.g. Gram staining. Collection of soil samples and water samples from different locations on campus for identification and quantification of bacteria in these samples through Gram staining and other techniques using McConkey's medium and Triple sugar iron medium. Learning the basic principles of light microscopy and the observation of bacterial cells under a compound microscope.
BSE314	BIOMECHANICS	3-0-0-0-4	Introduction to biomechanics. Biosensors, actuators and control. Analysis ofbiosystem as a flexible structure. Aerodynamics, hydrodynamics and locomotion. Biostatics and Biodynamics-I Mechanics of motion, friction, fracture. Biodynamics-II Work, energy and power. Biodynamics III. Fluid Mechanics Examples of Archimedes principles, Pascal Law, Bernoullis theory and the living world, Viscosity and turbulence, Human circulatory system.
BSE321A	STRUCTURAL BIOLOGY	2-0-2-2-10	Part I Principles of Protein Structure from primary sequence to three-dimensional structure. Elementary ideas of bonding and structure. The building blocks. Motifs of Protein structure. Prediction, design and engineering of protein structures. Part II. The Structural Basis of Protein Function. Four fundamental biochemical functions ofproteins, Recognition, Complementarity and Active Sites. Flexibility and Protein Function, Location and nature of Binding Sites, Functional Properties of, Structural Proteins, Catalysis: Overview, ActiveSite Geometry, Proximity and GroundState Destabilization, Stabilization ofTransition States, Active Site Chemistry. Control of Protein Function. Mechanisms of Regulation. Part III Determination of 3D Structures using Xray crystallography an overview of themethod. Laboratory

			experiments protein preparation for crystallization experiments, protein crystallization, Evaluating the quality of crystals, Cryoprotecting crystals at low temperature for data collection. Xray diffraction data collection and processing a demonstration session. **Course Reference**: 1. Protein Structure and Function, By Gregory. A. Petsko and Dagmar Ringe, New Science Press; 2. Introduction to Protein Structure, Branden & Tooze, Garland Publishing; 3. Outline of Crystallography for Biologists, David Blow, Oxford University Press.
BSE322	STRUCTURAL BIOLOGY & BIOINFORMATICS	3-0-0--4	Biological Databases; Global and local alignment; pair wise and multiple sequence alignment; Pattern searching in DNA & Protein sequences; Alignment tools, BLAST, FASTA, phylogenetic prediction, evolutionary tree construction, gene predictionin prokaryotes, eukaryotes; Protein structure classification; Structure prediction from sequence features, Comparative genomics.
BSE322A	BIOINFORMATICS & COMPUTATIONAL BIOLOGY	3-0-0-1-10	Introduction to bioinformatics, biological databases and their growth, Concept of homology and definition of associated terms, pairwise sequence alignment,dotmatrix plot, dynamic programming algorithm, global (Needleman Wunsch) andlocal (Smith Waterman) alignments, BLASTScoring matrices (PAM and BLOSUM families), gap penalty, statistical significance of alignment Multiple sequence alignment, Sum of pairs method, CLUSTAL W, Genetic AlgorithmPattern finding in protein and DNA sequencing, Gibbs Sampler, Hidden MarkovModel, Profile construction and searching, PSIBLASTIntroduction to phylogeny, maximum parsimony method, distance method (neighborjoining), maximum likelihood methodGene prediction in prokaryotes and eukaryotes, homology and abinitio methodsGenome analysis and annotation, comparative genomics **Course Reference**: 1. Bioinformatics: Sequence and Genome Analysis by David W. Mount, Cold Spring Harbor LaboratoryPress (2001); 2. Developing Bioinformatics Computer Skills by C. Gibas and P. Jam beck, Reilly (2001); 3. Biological Sequence Analysis: Probabilistic models of proteins and nucleic acids by R. Durbin, S. Eddy, A. Krogh and G. Mitchison, Cambridge University Press (1998)
BSE341	BIOCHEMICAL ENGINEERING	3-0-0--4	Fundamentals of Biochemical engineering: Stoichiometry and energetics of microbial metabolism, Transport phenomena, Enzyme catalyzed reactions and processes, Bioreactor design and applications, Sterilization, Instrumentation andcontrol, Bioseparations and bioprocesses: Downstream processing characteristics of biological materials, pretreatment methods; separation of cell biomass, adsorption, filteration, reverse osmosis, isoelectroc focusing, affinity based separation, polishing crystallization, drying, case studies; Process integration Bioprocess integration for efficient production and recovery, scaleup consideration, process monitoring and

			process economics; Environmental bioprocesses Interaction of mixed microbial population, applications, biological wastewater treatment, anaerobic, digesters, bioremediation.
BSE391	BSBE LAB-II BIOCHEMISTRY & BIOCHEM. ENGG.	0-0-9--5	Estimation of proteins by UV, Bradford and Lowry methods. SDSPAGE separation of proteins Enzyme Kinetics Salivary amylase different pH buffers andtemperature Chromatography Ion exchange/ HPLC/ GC/affinity Determination of molecular weights by Gel chromatography. Estimation of sugars/blood cholesterol Respiration of mitochondria and oxidative phosphorylation. Bioreactors and bioprocess engineering use computer simulation to explore mass transfer phenomena and cell growth kinetics. Bioseparation using smart polymers. Yeast antibody library screening use state-of-art combinatorial library screening methodology to obtain high affinity antibodies.
BSE392	BSBE LAB III STRUCTURAL BIOL. & BIOINFORMATICS	0-0-4--2	De novo protein design and artificial proteins: approaches used in designing and constructing novel proteins. Structure based drug design: Virtual screening techniques, designing pharmacaphore models, scoring function and their relevancein downsizing hit lists. Determination of Protein structure by Xray crystallography: protein purification, current methods in protein crystallization. Evaluating the quality of crystals, crystal freezing at low temperature for data collection. Ademonstration session on Xray diffraction data collection and processing. Bio informatics Training with Insight Molecular modeling package, Exercises involving homology modeling of protein structures, Pairwise and multiple sequence alignments using tools such as BLAST, FASTA, CLUSTAL and from GCGsuite of programs.
BSE398A	UG PROJECT (UGP-I)	0-0-0-0-4	UG PROJECT (UGPI)
BSE399A	UG PROJECT (UGP-II)	0-0-2-0-9	UG PROJECT (UGPII)
BSE411A	BIOMATERIALS	3-0-2-0-11	Types I Classes of Materials used in medicine: Polymers, Metals, Ceramics, Natural Materials and Composites. Degradable polymers and their use in medicine: Polymers, Hydrogels, Silicone biomaterials and medical fibers. Degradation of materials in the biological environment. Types of polymer degradation. Influence of polymer properties on degradation. Influence of biological environment on polymer degradation. Biological testing of biomaterials: In vitro assessment of materials for tissue compatibility. Invivo assessment of tissue compatibility. Host reactions to biomaterials and their evaluations: The role of adsorbed proteins in tissue response to biomaterials. Cell, extracellular matrix, and tissue interactions with biomaterials. Inflammation, wound healing and foreign body response to biomaterials. Immune response toforeign materials. Toxicity, tumorigenesis and biomaterials. Specific

			examples of applications of biomaterials in medicine. Biomaterial Science: **Course Reference**: 1. An Introduction to Materials in Medicine. Second Edition. Edited by: Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, and Jack E. Lemons. Publisher: Elsevier Academic Press.
BSE412A	BIOMATERIAL, PHYSIOLOGY & BIO-MEMS LABORATORY	1-0-6-0-9	1. Synthesis of biomaterials: Nanomaterials fabrication; Particles (electrospraying & single emulsion solvent evaporation) 2. Fiber (electrospinning) systems. Synthesis of biomaterials: Micro/Macromaterials fabrication Microporous polymeric hydrogel systems.Characterization of biomaterials: Morphology and size characterization (fibers, particlesand hydrogels) of fabricated samples using scanning electron microscopy (SEM).Characterization of biomaterials: Physical properties of fabricated samples (fibers andhydrogels) Mechanical properties using Bose Electroforce Mech. Testing System.Characterization of biomaterials: Physical properties of fabricated samples (hydrogels) Swelling kinetics.Blood: Blood collection, Blood count, Blood component separation (traditional methodsand modern biomaterials developed in BSBE like biofilters, cryogels and hydrogels),Microscopic analysis of blood components, Understanding blood clotting using differentbiomaterials developed in the department.Urine analysis, Fabricating an inhouse dialysis setup for blood purification using available tools in the department Blood pressure measurement: Concept of diastolic and systolic pressure and how tomeasure blood pressure and pulse rate.
BSE441	EVOLUTION OF BIOLOGICAL MACHINES	3-0-0--4	Living body as an example of finest designs for diverse activities, functionse.g., flying, swimming, reproduction, sensing, eating, etc. Evolution and natural selection as the means of optimization of biological machines at diverse scales: molecular, cellular, organismal and population. Principles of micro and macroevolution. Theories of evolution and Darwanian selection. Principles of generating diverse body plan and design in nature.
BSE452	BIOMATERIALS	3-0-0-0-4	Introduction to Materials Science: Bulk and surface properties of materials; Polymeric materials; synthesis, characterization, and fabrication methodsInert, biodegradable, hydrogels, Natural, Genetically engineered and Bioactive; Ceramics and glasses; Metals; Surface modification techniques. Biocompatibility of Biomaterials: Protein structure, interaction of proteins with synthetic materials Characterization of cellmaterial interactions; inflammatory responses; acute inflammation, chronic inflammation, foreign body response, assessment of material performance.
BSE454	INTRODUCTION TO TISSUE ENGG.	3-0-0-0-4	What is tissue engineering? Scope and objective of tissue engineering; Principlesof tissue engineering; Essential components of tissue engineering; Materials

			Science/Engineering aspects (degradable materials); Design and characterization of scaffolds (porosity, mechanical strength and 3D architecture); Cell Biology aspects (choice of cell type, progenitor cells and cell differentiations); Molecularbiology aspects (cell signaling molecules growth factors, cell attachment integrins);Drug delivery in tissue engineering; Commercial developments of tissue engineering;Future of tissue engineering.
BSE491	BSBE LAB IV BIOMECHANICS & BIOMATERIALS	0-0-6--4	Biomechanics: Human body motion analysis. Control of artificial arms/legs usingbiological principles. Rehabilitation applications of biomechanics. Biosensors andMEMS: Development of sensors for measuring pressure, temperature, force atthe fingertips and soles of the feet. Polymer spinners and micro lithography. Testing of synthetic materials Biomaterials: Biodegradable polymers synthesis, fabrication test theircharacteristic, computational simulation of biomaterial for their mechanical strength, tissue compatibility and prosthetic devices. Modeling natural material like wood, bamboo, fishbone, plant stem etc.., Modeling human tissue and tissue biomaterial interactions.
BSE498	PROJECT I	0-0-0-0-5	PROJECT I
BSE498A	UG PROJECT (UGP-III)	0-0-9-0-9	UG PROJECT (UGPIII)
BSE499	PROJECT II	0-0-0-0-4	PROJECT II
BSE499A	UNDER GRADUATE PROJECT IV	0-0-0-0-9	UP PROJECT (UGP II)
BSE601	PROFESSIONAL COMMUNICATION	1-0-0-0-0	1. CRITICAL READING: Context, how? is the text argued, Central claims, Kinds of reasoning, Examine Evidence, Examine Interpretations, Evaluations, Limitation of study; 2. CRITICAL WRITING: Learning to write through building of arguments, Hypothesis building, Conference Abstracts, Manuscripts, Reviews / Book chapters / Books, Proposals, Patents; 3. ORAL PRESENTATION: Conference, Scientific, Teaching, Popular; 4. ETHICS: Experimentation, Writing No prescribed textbook.
BSE601A	PROFESSIONAL COMMUNICATION	1-0-0-0-0	1. CRITICAL READING: Context, how is the text argued, Central claims, Kinds of reasoning, Examine Evidence, Examine Interpretations, Evaluations, Limitation of study; 2. CRITICAL WRITING: Learning to write through building of arguments, Hypothesis building, Conference Abstracts, Manuscripts, Reviews / Book chapters / Books, Proposals, Patents; 3. ORAL PRESENTATION: Conference, Scientific, Teaching, Popular; 4. ETHICS: Experimentation, Writing No prescribed textbook.
BSE602	LABORATORY METHODS	2-0-0-0-0	Demonstration based course. Usage of different equipments will be demonstrated. Demonstration based course. No text book.
BSE602A	LABORATORY METHODS	2-0-0-0-0	Demonstration based course. Usage of different equipments will be demonstrated. Demonstration based course. No text book.

BSE611	MODERN INSTRUMENTAL METHODS IN BIOLOGICAL SCIENCES	3-0-0-0-4	1. Applications of spectroscopic and other techniques to the study of biomolecules: UVVis spectroscopy, Circular dichroism, Fluorescence, NMR, Mass, IR and Raman spectroscopy, XRay diffraction; 2. Analysis of Proteins: Electrophoretic separation of proteins (single dimension native and denaturing gels, 2D and digital electrophoretic analysis), detection (staining, blotting and immunedetection) specialized applications (in vitro synthesis of protein, labeling and Mass spectrometry), ultra centrifugation; 3. Techniques with Radioisotopes: Introduction Isotopes and Radioactivity Ionization Effects, Measurement Units, Measurement Techniques, Autoradiography, Biological Uses of Radioisotopes, Tracer Dilution Technique, Radioimmuno assay; 4. Cellular Imaging Techniques: Microscopy: Phase contrast, Fluorescence, Atomic Force and confocal; 5. Electron Microscopy: Negative staining, cryo EM, Transmission EM and Scanning EM
BSE611A	MODERN INSTRUMENTAL METHODS IN BIOLOGICAL SCIENCES	3-0-0-0-9	1. Applications of spectroscopic and other techniques to the study of biomolecules: UVVis spectroscopy, Circular dichroism, Fluorescence, NMR, Mass, IR and Raman spectroscopy, XRay diffraction; 2. Analysis of Proteins: Electrophoretic separation of proteins (single dimension native and denaturing gels, 2D and digital electrophoretic analysis), detection (staining, blotting and immune detection) specialized applications (in vitro synthesis of protein, labeling and Mass spectrometry), ultracentrifugation; 3. Techniques with Radioisotopes: Introduction Isotopes and Radioactivity Ionization Effects, Measurement Units, Measurement Techniques, Autoradiography, Biological Uses of Radioisotopes, Tracer Dilution Technique, Radioimmunoassay; 4. Cellular Imaging Techniques: Microscopy: Phase contrast, Fluorescence, Atomic Force and confocal; 5. Electron Microscopy: Negative staining, cryo EM, Transmission EM and Scanning EM
BSE612	BIOCHEMICAL ENGINEERING	3-0-0-0-4	1. Introduction to biochemical engineering, bioprocesses, bioproducts and biochemical technology with specific examples Three lectures; 2. Upstream process: Microbial, mammalian and plant systems for bioprocess technology. Sterilization. Stoichiometry and energetics of microbial metabolism. Transport phenomena Five lectures; 3. Enzyme catalyzed reactions and processes. Cell and enzyme immobilization. Bioreactor design and applications. Instrumentation and control Six lectures; 4. Downstream process: Bioseparations, characteristics of biological materials, pretreatment methods, separation of cell biomass, adsorption, filtration, centrifugation, precipitation and extraction Four lectures; 5. Liquid chromatography principles, plate and rate theory, ion exchange, gel filtration, affinity chromatography, hydrophobic interaction and reverse phase chromatography Six lectures; 6. Integrated bioprocesses Bioprocess integration for efficient production and

			recovery, expanded bed separations, affinity precipitations, aqueous twophase processes, monolithic chromatographic separations Six lectures; 7. Polishing, crystallization, drying, scaleup consideration, process monitoring and process economics Three lecturesH. Environmental bioprocesses Interaction of mixed microbial population, biological wastewater treatment, anaerobic digesters, bioremediation Three lectures.I. Case studies and new developments of bioprocesses paper readings and presentations Four lectures **Course Reference**: 1. Blanch, H. W. and Clark, D. S. Biochemical Engineering. Marcel Dekker, Inc.; 2. Bailey, J. E. and Ollis, D. F. Biochemical Engieering Fundamentals. McGrawHill, Inc.; 3. Belter, P. A., Cussler, E. L. and Hu, W. S. Bioseparations: Downstream Processing for Biotechnology, John Wiley & Sons; 4. Desai, Mohamed. A. Downstream Processing of Proteins: Methods and Protocols. Humana Press; 5. Shuler, M. L. and Kargi, F. Bioprocess Engineering Basic Concepts.
BSE612A	BIOCHEMICAL ENGINEERING	3-0-0-0-9	1. Introduction to biochemical engineering, bioprocesses, bioproducts and biochemical technology with specific examples Three lectures; 2. Upstream process: Microbial, mammalian and plant systems for bioprocess technology. Sterilization. Stoichiometry and energetics of microbial metabolism. Transport phenomena Five lectures; 3. Enzyme catalyzed reactions and processes. Cell and enzyme immobilization. Bioreactor design and applications. Instrumentation and control Six lectures; 4. Downstream process: Bioseparations, characteristics of biological materials, pretreatment methods, separation of cell biomass, adsorption, filtration, centrifugation, precipitation and extraction Four lectures; 5. Liquid chromatography principles, plate and rate theory, ion exchange, gel filtration, affinity chromatography, hydrophobic interaction and reverse phase chromatography Six lectures; 6. Integrated bioprocesses Bioprocess integration for efficient production and recovery, expanded bed separations, affinity precipitations, aqueous twophase processes, monolithic chromatographic separations Six lectures; 7. Polishing, crystallization, drying, scaleup consideration, process monitoring and process economics Three lecturesH. Environmental bioprocesses Interaction of mixed microbial population, biological wastewater treatment, anaerobic digesters, bioremediation Three lectures; 8. Case studies and new developments of bioprocesses paper readings and presentations. **Course Reference**: 1. Blanch, H. W. and Clark, D. S. Biochemical Engineering. Marcel Dekker, Inc.; 2. Bailey, J. E. and Ollis, D. F. Biochemical Engieering Fundamentals. McGrawHill, Inc.; 3. Belter, P. A., Cussler, E. L. and Hu, W. S. Bioseparations: Downstream Processing for Biotechnology, John Wiley &

			Sons; 4. Desai, Mohamed. A. Downstream Processing of Proteins: Methods and Protocols. Humana Press; 5. Shuler, M. L. and Kargi, F. Bioprocess Engineering Basic Concepts
BSE613	BIOMATERIALS	3-0-0--4	Introduction to Materials Science: Bulk and surface properties of materials; Polymeric materials; synthesis, characterization, and fabrication methods Inert, biodegradable, hydrogels, Natural, Genetically engineered and Bioactive; Ceramics and glasses; Metals; Surface modification techniques. Biocompatibility of Biomaterials: Protein structure, interaction of proteins with synthetic material; characterization of cellmaterial interactions; inflammatory responses; acute inflammation, chronic inflammation, foreign body response, assessment of material performance.
BSE613A	BIOMATERIALS	3-0-0-2-11	Introduction to Materials Science: Bulk and surface properties of materials; Polymeric materials; synthesis, characterization, and fabrication methods Inert, biodegradable, hydrogels, Natural, Genetically engineered and Bioactive; Ceramics and glasses; Metals; Surface modification techniques. Biocompatibility of Biomaterials: Protein structure, interaction of proteins with synthetic material; characterization of cell material interactions; inflammatory responses; acute inflammation, chronic inflammation, foreign body response, assessment of material performance.
BSE614	TISSUE ENGINEERING	3-0-0-0-4	What is tissue engineering? Scope and objective of tissue engineering; Principles of tissue engineering; Essential components of tissue engineering; Materials Science/Engineering aspects (degradable materials); Design and characterization of scaffolds (porosity, mechanical strength and 3D architecture); Cell Biology aspects (choice of cell type, progenitor cells and cell differentiations); Molecular biology aspects (cell signaling molecules growth factors, cell attachment integrins); Drug delivery in tissue engineering; Commercial developments of tissue engineering; Future of tissue engineering.
BSE614A	TISSUE ENGINEERING	3-0-0-0-9	What is tissue engineering? Scope and objective of tissue engineering; Principles of tissue engineering; Essential components of tissue engineering; Materials Science/Engineering aspects (degradable materials); Design and characterization of scaffolds (porosity, mechanical strength and 3D architecture); Cell Biology aspects (choice of cell type, progenitor cells and cell differentiations); Molecular biology aspects (cell signaling moleculesgrowth factors, cell attachment integrins); Drug delivery in tissue engineering; Commercial developments of tissue engineering; Future of tissue engineering.
BSE617	DRUG DESIGN AND METABOLISM	3-0-0-0-9	Physicochemical Principles of Drug Action; Partition Coefficients; Receptor Effector Theories;Role of Second Messengers in Drug Action; Methods of Receptor Isolation,Characterization and Modeling Principles of

			Drug Design: Random Screening, Analogue Synthesis, Rational Design, Combinatorial Libraries; Enantiopure Drugs and Regulatory Implications; Theoretical Approaches: QSAR, Topliss Tree, MSA, CoMFA Neuroactive Drugs: Neurons and Neurotransmitters; Brainrelated Disorders and Chemotherapy; Drugs Interacting with Cholinergic, Adrenergic, Dopaminergic and Histaminic Receptors and Receptor subtypes Anticancer, Antimalarial, Antiviral, and Cardiovascular Drugs; Emerging Trends in Drug Design: Inhibitors of DNA Topoisomerase and Protein Farnesylation & Prenylation; GeneBased Medicines Biopharmaceuticals: Recombinant Proteins as Medicines and Vaccines Drug Delivery: Passive, Assisted and VectorBased Delivery of Conventional and GeneticDrugs; TissueSpecific Delivery of Antitumor Agents Drug Administration, Distribution, Metabolism and Elimination (ADME); Pathways of DrugMetabolism: Enzymology and Molecular Mechanisms; Detoxification of Diverse DrugClasses; Dose Formulation Induction and Inhibition of Drug Metabolism; Toxicological Aspects of Metabolism: MetabolicActivation of Environmental Carcinogens and DNA Damage; Drug Pharmacokinetics and Final Body Clearance. **Course Reference**: 1. Medicinal Chemistry: A Biochemical Approach, Thomas Nogrady; 2. Principles of Medicinal Chemistry, William O. Foye; 3. The Pharmacological Basis of Therapeutics: Goodman and Gilman; 4. Introduction to Drug Metabolism, G. Gordon Gibson and Paul Skett 15-SEP-14
BSE621	MODERN INSTRUMENTAL METHODS IN BIOLOGICAL SCIENCES	3-0-0-0-4	Applications of spectroscopic and other techniques to the study of biomolecules: UVV’s spectroscopy, Circular dichroism, Fluorescence, NMR, Mass, IR and Raman spectroscopy, XRay diffraction. Cellular Imaging Techniques: Microscopy: Phase contrast Nomarsky, Fluorescence, Atomic Force and confocal. Biophysical techniques to purify and study proteins. Dialysis, salting out and precipitaion by organic solvents, Ion exchange, gel filtration, reversed phase, affinity chromatography, ultracentrifugation, gel electrophoresis. Analysis of Proteins: Electrophoretic separation of proteins (single dimension native and denaturing gels, 2D anddigital electrophoretic analysis), detection (staining, blotting and immune detection)and purification (various chromatograpy, HPLC, immune precipitation) of proteins, and specialized applications (in vitro synthesis of protein, labeling,microsequence analysis, and Mas spectrometry)
BSE621A	MODERN INSTRUMENTAL METHODS IN BIOLOGICAL SCIENCES	3-0-0-0-9	Applications of spectroscopic and other techniques to the study of biomolecules: UVV’s spectroscopy, Circular dichroism, Fluorescence, NMR, Mass, IR and Raman spectroscopy, XRay diffraction. Cellular Imaging Techniques: Microscopy: Phasecontrast Nomarsky, Fluorescence, Atomic Force and confocal. Biophysical techniques to purify and study proteins. Dialysis, salting

			out and precipitaion by organic solvents, Ion exchange, gel filtration, reversed phase, affinity chromatography, ultra centrifugation, gel electrophoresis. Analysis of Proteins: Electrophoretic separation of proteins (single dimension native and denaturing gels, 2D anddigital electrophoretic analysis), detection (staining, blotting and immune detection) and purification (various chromatograpy, HPLC, immune precipitation) of proteins, and specialized applications (in vitro synthesis of protein, labeling, microsequence analysis, and Mas spectrometry)
BSE629	NEUROBIOLOGY	3-0-0-0-4	Cell and molecular biology of neurons. Membrane potential, local signaling and generation of action potential. Mechanism of synaptic transmission. Sensory pereception: Vision, hearing, taste, touch and smell. Movements: The motor systems, reflexes, Voluntary control of motion etc. Functions of hypothalamus limbic system and the Cerebral cortex learning and memory, sleep and dream.
BSE629A	NEUROBIOLOGY	3-0-0-0-9	Cell and molecular biology of neurons. Membrane potential, local signaling and generation of action potential. Mechanism of synaptic transmission. Sensory pereception: Vision, hearing, taste, touch and smell. Movements: The motorsystems, reflexes, Voluntary control of motion etc. Functions of hypothalamus limbic system and the Cerebral cortex learning and memory, sleep and dream.
BSE631	BIOCHEMISTRY STRUCTURAL BIOLOGY	3-0-0--4	A. Protein structure and folding: Building blocks of biopolymers, conformational studies of biomolecules, Ramachandran map, protein secondary and supersecondary structures, different classes of tertiary structures, overview of different experimental techniques to determine biomolecular structures, intermolecular interactions, protein foldingB. Enzymes and the structure function relationship: Enzyme kinetics, structural basis of catalytic activity, Michaelis Menten kinetics, Enzyme inhibitors and complex reaction schemes, protein and RNA enzymes, basic concepts of metabolism and designC. Nucleic acid structures: Double helical structures of RNA and DNA, functional versatility of RNA, proteinDNA interactions D. Membrane proteins: Lipids, bilayer assembly, biological membranes as solvent for membrane proteins, structural principles of membrane proteins, channels and receptors, signal transduction and GPCRs The Molecules of Life: Physical and Chemical Principles. **Course Reference**: 1. John Kurian, Boyana Konforti and David Wemmer, Garland Science, New York (2013) Biochemistry. L. Stryer W. H. Freeman & Company, New York (4th Edition); 2. Introduction to Protein Structure. Carl Branden & John Tooze, Garland Science (2nd Edition)
BSE631A	BIOCHEMISTRY	3-0-0-0-9	Basic concepts and historical account. Model systems.

	STRUCTURAL BIOLOGY		Animal body plan: Axes and germ layers. Organizers. Morphogenesis. Cell fate determination and cell differentiation. Cellcell communication during development. Genes and development: gene expression and their regulation. Regeneration and aging. Environmental regulation of animal development.
BSE632	STRUCTURAL BASIC OF PROTEIN FUNCTION	3-0-0--4	Conformational studies of biomolecules, protein secondary structure, 3D structures of proteins, DNA structures, membrane proteins. Xray and NMR techniques, electron crystallography, other spectroscopic techniques used to deduce structuralinformation (CD, IR, FTIR, Raman, Solid State NMR, ESR etc.), Homology modeling, computational studies to understand the structure function relationships of proteins, molecular mechanics and dynamics, force fields, biomolecular simulation programs. Structural genomics, highthroughput structuredetermination.
BSE632A	STRUCTURAL BASIC OF PROTEIN FUNCTION	3-0-0-0-9	Conformational studies of biomolecules, protein secondary structure, 3Dstructures of proteins, DNA structures, membrane proteins. Xray and NMR techniques, electron crystallography, other spectroscopic techniques used to deduce structuralinformation (CD, IR, FTIR, Raman, Solid State NMR, ESR etc.), Homology modeling, computational studies to understand the structure function relationships of proteins, molecular mechanics and dynamics, force fields, biomolecular simulation programs. Structural genomics, highthrough put structure determination.
BSE633	BIOINFORMATICS AND COMPUTATIONAL BIOLOGY	2-0-0-0-4	Introduction to Molecular Genetics, The Human Genome Project, Biological databases, Gene prediction, Analysis of genomic sequences, Pair wise andmultiple sequence alignments, Bioinformatics tools, Hidden Markov Models, Conformational studies of biomolecules, Globular and membrane proteins, Protein folding problem, Homology modeling, Simulation studies of proteins and nucleicacids.
BSE633A	BIOINFORMATICS AND COMPUTATIONAL BIOLOGY	3-0-0-0-9	Introduction to Molecular Genetics, The Human Genome Project, Biological databases, Gene prediction, Analysis of genomic sequences, Pair wise and multiple sequence alignments, Bioinformatics tools, Hidden Markov Models, Conformational studies of biomolecules, Globular and membrane proteins, Protein folding problem, Homology modeling, Simulation studies of proteins and nucleicacids.
BSE634	FUNCTIONAL GENOMICS	3-0-0--4	Introduction; The impact of genomics on biological research; Identification ofa large set of genes involved in a biological process; High throughput expression analysis; Genomewide search for interacting partners; Identification of alternatively spliced genes; Sequence variations and disease susceptibility; Pharmacogenomics; Proteomics; Functional genomics in model organisms; High throughput phenotypic analysis; Recent developments in genomics.

BSE634A	FUNCTIONAL GENOMICS	3-0-0-0-9	Introduction; The impact of genomics on biological research; Identification of a large set of genes involved in a biological process; High throughput expression analysis; Genome wide search for interacting partners; Identification of alternatively spliced genes; Sequence variations and disease susceptibility; Pharmacogenomics; Proteomics; Functional genomics in model organisms; High throughput phenotypic analysis; Recent developments in genomics.
BSE636	HUMAN MOLECULAR GENETICS	2-0-0--4	Simple Mendelian traits; Loss of function mutations; Gain of function mutations; Gene interactions; Dynamic mutations; Genetics of neoplasia; Genomic imprinting and human disease; Xinactivation and DNA methylation; Gene mapping and positional cloning; Mutifactorial inheritance; Genetics of behavioral disorders; Pharmacogenetics and biochemical genetics; Animal models in human genetics: Methods used for diagnosis and detection of gene mutations; Gene Therapy.
BSE636A	HUMAN MOLECULAR GENETICS	3-0-0-0-9	Simple Mendelian traits; Loss of function mutations; Gain of function mutations; Gene interactions; Dynamic mutations; Genetics of neoplasia; Genomic imprinting and human disease; Xinactivation and DNA methylation; Gene mapping and positional cloning; Mutifactorial inheritance; Genetics of behavioral disorders; Pharmacogenetics and biochemical genetics; Animal models in human genetics: Methods used for diagnosis and detection of gene mutations; Gene Therapy.
BSE651	CELLULAR MOLECULER BIOLOGY	3-0-0-0-4	1. Molecular Genetic Techniques and Genomics: Genetic analyses of mutations to indentify and study genes; DNA cloning and characterization; Genome wide analyses of gene structure and gene expression; Inactivating the function of specific genes in eukaryotes; Identifying and locating human disease genes; 2. Molecular Structure of Genes and Chromosomes: Chromosomal organization genes and noncoding DNA; Mobile DNA; Structural organization of eukaryotic chromosomes; organelle DNAs; 3. Transcriptional Control of Gene Expression: Eukaryotic gene control and RNA polymerase; regulatory sequences in protein coding genes; activators and repressors of transcription; mechanism of transcription activation and repression; 4. Posttranscriptional Gene Control: Processing of eukaryotic premRNA; transport across nuclear envelope; cytoplasmic mechanism of post transcriptional control; processing of rRNA and tRNA; 5. Cell signalling: Signalling molecules and cell surface receptors; intracellular signal transduction; 6. protein coupled receptors; 7. Membrane trafficking: Translocation of secretory proteins across the ER membrane; protein modifications, folding and quality control in the ER; export and sorting of proteins; 8. Eukaryotic cell cycle: Biochemical and genetics studies on cell cycle; mechanisms regulating mitotic events; meiosis a special type of cell division. **Course Reference**: 1. Molecular Cell Biology, by Lodish

			et al (5th edition or recent), W.H. Freeman and Company, New York Molecular Biology of the Cell, by Alberts et al (4th edition or later), Garland Sciences, New York
BSE651A	CELLULAR MOLECULER BIOLOGY	3-0-0-0-9	1.Molecular Genetic Techniques and Genomics: Genetic analyses of mutations to indentify and study genes; DNA cloning and characterization; Genome wide analyses of gene structure and gene expression; Inactivating the function of specific genes in eukaryotes; Identifying and locating human disease genes; 2. Molecular Structure of Genes and Chromosomes: Chromosomal organization genes and noncoding DNA; Mobile DNA; Structural organization of eukaryotic chromosomes; organelle DNAs; 3. Transcriptional Control of Gene Expression: Eukaryotic gene control and RNA polymerase; regulatory sequences in protein coding genes; activators and repressors of transcription; mechanism of transcription activation and repression; 4. Posttranscriptional Gene Control: Processing of eukaryotic premRNA; transport across nuclear envelope; cytoplasmic mechanism of posttranscriptional control; processing of rRNA and tRNA; 5. Cell signalling: Signalling molecules and cell surface receptors; intracellular signal transduction; G protein coupled receptorsF. Membrane trafficking: Translocation of secretory proteins across the ER membrane; protein modifications, folding and quality control in the ER; export and sorting of proteins; 6. Eukaryotic cell cycle: Biochemical and genetics studies on cell cycle; mechanisms regulating mitotic events; meiosis a special type of cell division. Molecular Cell Biology, by Lodish et al (5th edition or recent), W.H. Freeman and Company, New YorkMolecular Biology of the Cell, by Alberts et al (4th edition or later), Garland Sciences, New York.
BSE652	DEVELOPMENTAL BIOLOGY	3-0-0--4	1. Concepts in Developmental Biology: A. Axis specification and patterning SIX lecturesB. Cell fate Determination, Specification, Commitment, Differentiation, Proliferation Vs Differentiation, Induction, Competence, Lateral inhibition TEN lecturesC. Migration THREE lectures; 2. Methods of studying Developmental Biology: A. Classical techniques e.g. Cell labeling, grafting ONE lectureB. Candidate gene approach i. Saturated mutagenesis screens FOUR lectures ii. Lessons from other species/contexts FOUR lectures; 3. Development and disease SIX lectures; 4. Developmental mechanisms of evolutionary change SIX lectures. **Course Reference**: 1. Recommended Text Book Developmental Biology, Scott F. Gilbert Ninth Edition
BSE652A	DEVELOPMENTAL BIOLOGY	3-0-0-0-9	1. Concepts in Developmental Biology: A. Axis specification and patterning SIX lectures B. Cell fate Determination, Specification, Commitment, Differentiation, Proliferation Vs Differentiation, Induction, Competence, Lateral inhibition TEN lectures C. Migration

			THREE lectures; 2. Methods of studying Developmental Biology: A. Classical techniques e.g. Cell labeling, grafting ONE lecture; B. Candidate gene approach i. Saturated mutagenesis screens FOUR lectures ii. Lessons from other species/contexts FOUR lectures; 3. Development and disease SIX lectures; 4. Developmental mechanisms of evolutionary change. **Course Reference**: 1. Recommended Text Book Developmental Biology, Scott F. Gilbert Ninth Edition
BSE653	FUNCTIONAL GENOMICS	3-0-0-0-4	Introduction; The impact of genomics on biological research; Identification of a large set of genes involved in a biological process; High throughput expression analysis; Genome wide search for interacting partners; Identification of alternatively spliced genes; Sequence variations and disease susceptibility; Pharmacogenomics; Proteomics; Functional genomics in model organisms; High throughput phenotypic analysis; Recent developments in genomics.
BSE653A	FUNCTIONAL GENOMICS	3-0-0-0-9	Introduction; The impact of genomics on biological research; Identification of a large set of genes involved in a biological process; High throughput expression analysis; Genomewide search for interacting partners; Identification of alternatively spliced genes; Sequence variations and disease susceptibility; Pharmacogenomics; Proteomics; Functional genomics in model organisms; High throughput phenotypic analysis; Recent developments in genomics.
BSE654	HUMAN MOLECULAR GENETICS	3-0-0-0-4	Simple Mendelian traits; Loss of function mutations; Gain of function mutations; Gene interactions; Dynamic mutations; Genetics of neoplasia; Genomic imprintingand human disease; Xinactivation and DNA methylation; Gene mapping and positional cloning; Mutifactorial inheritance; Genetics of behavioral disorders; Pharmacogenetics and biochemical genetics; Animal models in human genetics: Methods used for diagnosis and detection of gene mutations; Gene Therapy.
BSE654A	HUMAN MOLECULAR GENETICS	3-0-0-0-9	Simple Mendelian traits; Loss of function mutations; Gain of function mutations; Gene interactions; Dynamic mutations; Genetics of neoplasia; Genomic imprintingand human disease; Xinactivation and DNA methylation; Gene mapping andpositional cloning; Mutifactorial inheritance; Genetics of behavioral disorders; Pharmacogenetics and biochemical genetics; Animal models in human genetics: Methods used for diagnosis and detection of gene mutations; Gene Therapy.
BSE656	NEUROBIOLOGY	3-0-0-0-4	Cell and molecular biology of neurons. Membrane potential, local signaling and generation of action potential. Mechanism of synaptic transmission. Sensory pereception: Vision, hearing, taste, touch and smell. Movements: The motor systems, reflexes, Voluntary control of motion etc. Functions of hypothalamus limbic system and the Cerebral cortex learning and memory, sleep and dream.

BSE656A	NEUROBIOLOGY	3-0-0-0-9	Cell and molecular biology of neurons. Membrane potential, local signaling and generation of action potential. Mechanism of synaptic transmission. Sensory pereception: Vision, hearing, taste, touch and smell. Movements: The motor systems, reflexes, Voluntary control of motion etc. Functions of hypothalamus limbic system and the Cerebral cortex learning and memory, sleep and dream.
BSE699	M.TECH THESIS	------	M. Tech. Thesis
BSE701	SEMINAR	----0	Seminar
BSE702	SEMINAR	----0	Seminar
BSE799	PHD THESIS	------	Ph. D. Thesis
ESO206A	PRINCIPLES OF BIOTECHNOLOGY	3-0-0-0-9	Introduction to coordinate system and phase space, review of vectors and tensors, dynamics ofsystem of particles, steady mass flow and variable mass problems, coordinate transformationinvolving 3D rotations and the concept of angular velocity, kinematics of rigid bodies, kineticsof rigid bodies, general planar motions, general 3D motions, advanced examples. **Course Reference**: 1. Engineering Mechanics, Dynamics, vol. 2, J.L. Meriam and L.G. Kraige; 2. Engineering Mechanics Dynamics, R.C. Hibbeler; 3. Engineering Mechanics, Den Hartog; 4. Principles of Dynamics, Donald T. Greenwood (Advanced Text).
ESO219	INTRODUCTION TO BIOLOGY	3----4	Chemical Foundation for Cells: Carbon Compounds in Cells, Cell Structure and Function. Principles of Cell structure and function: Cell Division and Mitosis, Meiosis. Flow of information: Chromosome and DNA, DNA to protein, Control of genes, recombinant DNA and genetic engineering Tissue, Organs and Homeostasis Nervous Systems, Sensory Reception, Endocrine Control, Protection, Support, and Movement, Circulation, Immunity, Respiration, Digestion andHuman Nutrition, Reproduction and Development. Round Rules of Metabolism, How Cells Acquire Energy, and How Cells release stored energy.
LIF101A	INTRODUCTION TO BIOLOGY	2-0-0-0-6	Part I Principles of Cellular Life Effects of waters polarity: importance of cohesion of water molecules for life; moderation of Earths temperature; Suitability of water as a solvent for life. Carbon and the molecular diversity of life. Polymer principles: most macromolecules of life are polymers; variety from a small set of monomers. Carbohydrates structure and function Proteins structure and function Lipids structure and function Nucleic acids structure and function Introduction to metabolism: pathways; energy transformation in organisms follow the laws of thermodynamics; life at the expense of free energy; enzymes as biocatalysts; regulation of metabolism B. Cell: Structural and functional unit of life (5 lectures)Structure: how we study cells; birds eye view of cell structure; subcellular structures; organelles;

			cytoskeleton; cell surface and junctions Membrane structure and function; traffic across membranes Cellular respiration; photosynthesis; cell communication; cell cycle Part II Principles of Inheritance: Information processing in living systems Introduction to heredity: inheritance of chromosomes; comparison of asexual and sexual reproduction; meiosis and sexual life cycles; origins of genetic variation Mendels discoveries; extending Mendelian genetics; Mendelian inheritance in human Chromosomal basis of inheritance: Relating Mendels principles to chromosomes; Sex chromosomes and sexlinked inheritance; errors and exceptions in chromosomal inheritance DNA as the genetic material; DNA replication and repair Gene to protein: connection between genes and proteins; synthesis and processing of RNA; synthesis of protein Organization and control of prokaryotic genomes Organization and control of eukaryotic genomes: chromatin structure; control of gene expression DNA technology and genomics: DNA cloning; DNA analysis and genomics; practical applications of DNA technology Genetic basis of development: single cell to multicellular organism;

CHEMICAL ENGINEERING

CHEMICAL ENGINEERING

BT — Template No. CHE-1

SEMESTER							
1st	2nd	3rd	4th	5th	6th	7th	8th
MTH101A [11]	CHM102A [08]	CHE251A [09]	ESC201A [14]	CHE312A [09]	CHE331A [09]	CHE453A [11]	HSS-5 (Level-2) [09]
ESC101A [14]	MTH102A [11]	TA202A [06]	TA201A [06]	CHE313A [09]	CHE381A [11]	CHE492A [08]	OE-5 [09]
CHM101A [03]	LIF101A [06]	HSS-2 (Level-1) [11]	COM200A [05]	CHE352A [05]	CHE391A [08]	OE-3 [09]	OE-6 [09]
PHY103A [11] PE101A [03]	PHY101A [03] PHY102A [11]	ESO-1 [11] (ESO201A)	SO-1 [11] (CSO201A/CSO202A)	ESO-3 [14] (ESO205A)	HSS-4 (Level-2) [09]	OE-4 [09]	DE-3 [09]
ENG112A/ HSS-1 (Level-1) [11]	TA101A [09] PE102A [03]	ESO-2 [11] (ESO208A)	CHE211A [09] CHE221A [09]	HSS-3 (Level-2) [09] CHE300A [02]	UGP-2/DE-1 [09] (CHE398A)	UGP-3/DE-2 [09] (CHE497A)	DE-4 [09]
-	-	-	CHE261A [06]	OE-1 [09]	OE-2 [09]	DE-M2 [05] (Optional)*	UGP-4 [09] (CHE498A) (Extra Credits)
			-	UGP-1 [04] (CHE349A) (Extra Credits)	-		
				DE-M1 [05] (Optional)*		-	-
53	51	48	60	57 – 66	55	46/51	45/54

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	105	Credits
Department Elective (DE)	:	36	Credits
Open Elective (OE)	:	54	Credits
SO/ ESO	:	47	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	**415**	**Credits**

REMARKS:

1) *DE M1 & M2 are Modular Courses which are optional summer training and may count towards DE credits.
2) DE credits may include 18 credits from UGP-2 and UGP-3.
3) UGP-1 and UGP-4 are optional and do not count towards DE/OE credits.
4) Upto 18 DE credits may be waived from the minimum requirements for students opting for Dual Degree in Chemical Engineering itself.
5) Upto 36 OE credits may be waived from the minimum requirements for students opting for Dual Degree in another department or the Double Major programme.

BT-MT (PG Part – Category – A) *(from the same department)*

Template No. CHE-2

PG Component				
7th	8th	SUMMER	9th	10th
CHE701A [0]	CHE702A [0]	M.Tech. Thesis [09] (CHE699A) (if required)	M.Tech. Thesis [09] (CHE699A) / DE/OE PG [09] (if required)	M.Tech. Thesis [36] (CHE699A)
OE PG-1 [09] OE PG-2 [09]	M.Tech. Thesis [09] (CHE699A) / DE PG-1 [09]* DE PG-2 [09]* OE PG-3 [09] OE PG-4 [09] M.Tech. Thesis [09]		M. Tech. Thesis [27]	
18	45	09	36	36

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION:

PG Component	:	54	Credits
Thesis	:	81	Credits

Basket - A

CHE611A [09]
CHE621A [09]
CHE631A [09]
CHE641A [09]

REMARKS:

1) All courses to be taken with the permission of Supervisor/ DUGC Convener.
2) *DE PG 1 & 2 should be selected from Basket – A.
3) CHE701A and CHE702A (seminar courses) are mandatory.
4) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech. part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
5) 18 DE credits may be used from the BT minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the BT programme and counted towards PG requirements.
6) Upto 36 OE credits may be used from the BT minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the BT programme and counted towards PG requirements.

DOUBLE MAJOR	Template No. CHE-4
Odd Semester	**Even Semester**
Pre-Requisites	
ESO201A [11]	CSO201A [11]/ CSO202A [11]
ESO208A [11]	
ESO205A [14]	
Mandatory CHE Courses	
CHE251A [09]	CHE211A [09]
CHE312A [09]	CHE221A [09]
CHE313A [09]	CHE261A [06]
CHE352A [05]	CHE331A [09]
CHE453A [11]	CHE381A [11]
CHE492A [08]	CHE391A [08]
51	52

<u>TOTAL MANDATORY CREDITS FOR SECOND MAJOR IN CHEMICAL ENGINEERING:</u> 103 CREDITS

<u>REMARKS:</u>

1) Depending on overlap with course contents of parent department, some equivalent CHE courses may be waived on a case-to-case basis.
2) Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.

MINOR	Template No. CHE-5
Title	CHEMICAL ENGINEERING
C O U R S E S	CHE251A [09]
	CHE261A [09]
	CHE313A [09]
	CHE331A [09]
	36

Template No. CHE-3
10^{th}
.Tech. Thesis [36] HE699A)
36

DEPARTMENT OF ChE			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Courses ID**
ChE100	INTRODUCTION TO PROFESSION	1-0-2-0-0	What is engineering visvis basic Science? What is Chemical Engineering? What do Chemical Engineers do? Diversity of employment opportunities; Intimate connections with other physicochemical sciences, biological and biomedical sciences, and other engineerings: case studies and examples; Historical perspectives and needs, e.g., petrochemical industries, pulp and paper, textiles; Concerns of chemical engineering: traditional areas, environment, energy, new materials, bioengineering and biotechnology, food, health; Safety, IPR, Professional ethics; Frontiers: role and future of Chemical Engineering in the computer/informationrevolution; biomolecular revolution (e.g., nanodevices); Basic tools of Chemical Engineering: physicochemical, mathematical and biological sciences, transport phenomena, thermodynamics, kinetics and reactors, design; Concept of unitoperations and descriptions of important unit operations; Concepts of scaleup, modeling and simulation: from molecular to terrestrial (e.g., ecology) scales; Visit to research laboratories of the department and other specially chosen laboratories in the Institute to introduce chemical engineering concerns; Simple laboratory demonstrations; Screening of educational videos from AIChE and IChem E, as well as from Indian industries; Plant visits.
ChE211	FLUID MECHANICS	3-1-0-1-4	Review of NavierStokes (NS) equations; nondimensionalization of NS equations; introduction to turbulence; analogies; correlations for fluid flow Short introductionto nonNewtonian flows, Engineering Bernoulli Equation; f vs. NRe charts; K factorsand equivalent lengths for various fittings; hydraulic diameter; Head vs. Q plotsof centrifugal pumps; NPSH, cavitation and priming; pipeline system design including pseudosteady state approximation; flow measurements; compressors and blowers. Compressible flows in conduits, Mixing and Agitation: Power consumption; mixing times; scaleup, Characterization of solids; fundamentals of twophase flow; flow through packed beds and in fluidized beds (pressuredrops, loading and flooding); pneumatic and hydraulic transportation. Filtration, Centrifuges and cyclones (including some recent models).
ChE211A	FLUID MECHANICS AND ITS APPLICATION	3-0-0-0-9	Introduction: Fluid, fluid types (Newtonian/ NonNewtonian, compressible/incompressible), physical properties, introduction to viscosity, continuum hypothesis Fluid statics: Pressure distribution in a static fluid, hydrostatic forces on submerged plane surfaces (no. curved surfaces). Kinematics: Substantial derivative, streamline, path lines, streakline, timeline, flow visualization videos. Integral/macroscoQic balances: Control volume, Reynolds transport theorem (introduction and interpretation only. Noderivation), conservation of mass, energy and linear momentum.

			Application of macroscogic balances: Losses in expansion, I force on a reducing bend, injet ejector. Differential balances: Differential equation of mass conservation, differential equation of linear momentum, constitutive equations, NavierStokes equations. Applications to couette flow between a fixed and a moving plate, flow due to pressure gradient between two fixed plates, fully developed laminar pipe flow Hagen Poiseuille flow, pipe flow with a power law fluid Dimensional analysis and similarity Buckingham Pi theorem, nondimensionalization of continuity and Navier Stokes equations, introduction of dimensionless numbers. **Course Reference**: 1. Vijay Gupta and Santosh K. Gupta. Fluid Mechanics and its applications. Edition,2011, New Age International (P) Limited, New Delhi; 2. W.L. McCabe, J.C. Smith and P. Harriot, Unit Operations of Chemical Engineering, edition, 2001, McGrawHill Co, Singapore Robert W. Fox, Philip J. Pritchard, and Alan T. Mcdonald; 3. Introduction to Fluid Mechanics, 7th Edition, 2009, Wiley India Pvt Ltd; 4. F. M. White, Fluid Mechanics, 6th edition, 2008, Tata McGrawHill Publishing Company Limited, New Delhi
ChE221	CHEMICAL ENGINEERING THERMODYNAM ICS	3-1-0-1-4	Review of I and II Laws of Thermodynamics, PVT Relations of Pure Fluids Graphical Tabular and Mathematical representaion; Generalized compressibility chart; Generalized EOS; Thermodynamic Potentials; Maxwell Relations, Thermodynamic Property Relations, Thermodynamic properties of real gases, Multicomponent mixtures, Properties of solutions, Phase Equilibrium (VLE, LLE, VLLE), Review of Thermochemistry; Chemical reaction equilibria.
ChE221A	CHEMICAL ENGINEERING THERMODYNAM ICS	3-0-0-0-9	Laws of Thermodynamics: Introduction, Work, Heat, Energy , Review Iof first Law for closed and open systems, properties of ideal gas andreal fluids Reversibility and Entropy: Reversibility, the second law of thermodynamics, Carnot engine, entropy change for closed and open system Fundamental Equations: Thermodynamics calculus, thermodynamics derivatives, Euler’s theorem for homogeneous functions, Legendre’s transformations, Derivative in terms of measurable properties Microscopic origin of entropy and elementary statistical mechanics Equilibria and stability: Equilibrium critera, stability criteria, Maxwell construction, binodals , spinodals, Gibbs Phase Rule, Clapeyronequation and vapor pressure. Correlations Pure component properties: Equation of state, Ideal gas heat capacities, fundamental equations fiom experimental data, fugacity and corresponding states Mixture Properties: Mixing function, partial molar quantities, Gibbs relation for mixtures, partial Molar quantities from experimental data, Ideal gas mixtures and fugacities, ideal mixtures and activities,excess functions, excess Gibbs free energy models, infinite dilutionproperties and Henry’s Law Chemical, Biochemical and Engineering Thermodynamics, S. Sandler, Wiley(2006). **Course Reference**: 1. Essential Thermodynamics by A. Z. Panagio to poulos, Drios Press, Princeton (2011); 2. Chemical Engineering Thermodynamics, by Smith, van Ness and Abbott, Ed, McGrawHill (2005); 3. Introduction to Chemical

			Engineering Thermodynamics, J. E. Elliot, C. T. Lira, PrenticeHall (1999); 4. Chemical Engineering Thermodynamics, Y. V. Rao, Universities Press, India (1997)
ChE251	CHEMICAL PROCESS CALCULATION	3-1-0-1-4	Guidelines for Problem Solving; Review of Basic concepts Process variables & properties, Degree of Freedom, Steady State Material Balances in nonreacting systems and reacting system, Recycle & purge, elemental vs. Species balance, combustion of fossil fuels, Steady State Material balances in Multiphase systems, Steady State Energy Balances in nonreacting and reacting systems, DeCoupled & coupled mass & energy balances, Calculations for network of units with recycle and bypass, Process Flow sheeting with sequential modular calculations, Unsteady State Balances.
ChE251A	INTRODUCTION TO CHE AND PROCESS CALCULATION	3-0-0-0-9	Objectives and Overview, Historical Perspective of Chemical Engineering, Role of a Chemical Engineer, Role of Balance Calculations, Review of Basic Concepts. Steadystate Material Balances in Nonreacting Systems: on Single Units, Basis of calculation; number of independent equations, Development of Degrees of Freedom; specification of variables. Balances on MultipleUnit Processes: Recycle and bypass. Balances in Reacting Systems: Stoichiometry, multiple reactions, Recycle and Purge.Element (atomic) versus Species (molecular balances): Combustion of Fossil Fuels, ultimate (elemental) and proximate analyses, combustion chemistry incomplete combustion, theoretical and excess. Material Balances in Multipbase Systems: Phase Rule, GasLiquid Systems, vaporliquid equilibrium (VLE) calculations, isothermal flashvaporization, Immiscible and Partially Miscible Liquid Systems, SolidLiquid Systems; saturation solubility and crystallization. **Course Reference**: 1. Basic Principles and Calculations in Chemical Engineering; 2. D. M. Himmelblau, 7th ed., Prentice Hall of india Pvt. Ltd., New Delhi; 3. Elementary Principles of Chemical Processes, R. M. Felder and R. W. Rousseau, 2nd ed., Wiley, New York, 1986.
ChE261A	CHEMICAL PROCESS INDUSTRIES	2-0-0-0-6	Unit operations and processes, flowchart Inorganic Industry: Ammonia production, steam reforming, Nitric acid production, Ammonium nitrate production, Ureaproduction, Ammonium phosphate/sulphate production, Methanol production, Caustic soda and chlorine production Natural products: Overview of production of soap and oils, transesterification process, glycerol production, hydrogenation and saponification Organic chemicals: Steam cracking of hydrocarbons, chemicals from C2, C3, aromatics (suggested chemicals vinyl chlorides, ethylene oxide, ethylene glycol, styrene, phenol, maleicanhydride, pthalic anhydride, isopropanol, cumene) **Course Reference**: 1. Petroleum & Petrochemicals: Refining/crude distillation, FCC, J.H. Gary, G.E. Handwerk and M.J. Kaiser; Petroleum refining: Technology and economics, 51^{th} ed. (2007), CRC Press Kirkothmer Encyclopedia of Industrial Chemistry, 2003; 2. Ullmann's Encyclopedia of Industrial Chemistry, 2003, Riegel's Handbook of Industrial Chemical and Biotechnology, Editor: James A. Kent, 11^{th} edition; Survey of India; Annual Hindu

			Publication. R.N. Shreve and G.T. Austin; Chemical Process Industries; 51h Edn., McGraw Hill, NewYork, 1995.
ChE300A	CHEMICAL ENGINEERING COMMUNICATIO N SKILLS	0-0-2-0-2	Chemical Engineering Communication Skills
ChE312	HEAT AND MASS TRANSFER	3-1-0-1-4	Heat conduction, Molecular diffusion, Convective heat transfer (laminar & turbulent), convective mass transfer (laminar & turbulent), simultaneous heatand mass transfer, wet bulb and adiabatic saturation, Interface mass transfer; Boiling: pool and convective boiling, correlations, Condensation: film wise and dropwise condensation, correlations, Radiation: thermal radiation, radiation properties, view factors, heat exchange between surfaces, Heat exchanger design: Shell and tube, compact exchangers, reboiler, and condenser, Evaporators: type of equipment, single and multiple effect evaporators, Crystallization: phase equilibria, crystal growth, types of equipment, design, Aspen/Matlab should beused wherever possible.
ChE312A	HEAT TRANSFER & ITS APPLICATIONS	3-0-0-0-9	Introduction to heat transfer, scope, variables and general applications Modes of heat transfer (conduction, radiation, convection); Heat conduction: Fourier law, thermal conductivity in gases, liquids and solids and their estimations Radiation: thermal radiation, radiation properties, view factors, Heat exchange between surfaces: General differential energy balance equation, dimensionless form, simplified forms, boundary conditions,similarity and scaling analysis Steady state conduction in stagnant fluids and solids, fins, definition of heat transfer coefficients Unsteady heat conduction in stagnant fluids and solids. Heisler charts, numerical solutions and Matlab, etc. Convective heat transfer (laminar): heat transfer in ducts, flat plate, 3falling film, natural convection, correlations Convective heat transfer (turbulent): heat **Course Reference**: 1. Frank P. Incropera and David P. Dewitt, Fundamentals of Heat and Mass Transfer, Sixth ed. Wiley India; 2. J.P. Holman, Heat Transfer, McGraw Hill; latest International or Indian edition; 3. D. Q. Kern, Process Heat Transfer, McGraw Hill, New York, 1950.
ChE313	SEPARATION PROCESSES	3-0-0-1-4	Mass transfer equipment: continuous contact and staged contact units for absorption, extraction, distillation, adsorption, humidification, drying, Phase equilibria: phase diagrams, VLE, GLE, SLE; estimation of binary and multicomponent phase equilibria, Single stage (steady state): binary and multicomponent, Single stage unsteady state: (distillation, drying, adsorption [blow down]), Separations without reflux: isothermal cases: stage contactor: McCabe Thiele method, stage efficiency, matrix method, Thomas method forsolution, continuous contact (HTU, NTU), Separations without reflux: nonisothermal cases (absorption, adsorption, drying, humidification): McCabeThiele method, numerical solutions, Separations with reflux: distillation, extraction and adsorption, McCabeThiele and matrix method; continuous contact, Membrane separation processes: fundamentals, introduction,

			different types of processes, Design of gas liquid, liquid liquid contactor; staged and continuous contact,Estimation of stage efficiencies, Shortcut methods for distillation. Aspen should be used as much as possible.
ChE313A	MASS TRANSFER & ITS APPLICATIONS	3-0-0-0-9	Introduction: Definition of rate of reaction, types of reactors, industrial reactions and reactors. Basic Concepts in Chemical Kinetics: reaction rate constant, reaction order, elementary reactions and molecularity, reversible reactions, nonelementary reactions. Collection and Analysis of Rate Data: simple constant volume arid variable volume reaction systems, differential and integral methods ofkinetic analysis, halflives, leastsquares analysis. Nouelementary Homogeneous Reactions: reaction mechanisms, pseudosteady state hypothesis, chain reactions, enzyme reactions Isothermal Reactor Design: batch reactor, mixed flow reactor, plug flow reactor; multiple reactor systems Design for Multiple Reactions in Isothermal H. Scott Fogler, Elements of Chemical Reaction Engineering;4th edition, 2006, PrenticeHall of India, New Delhi.
ChE331	CHEMICAL REACTION ENGINEERING	3-1-0-1-4	Introduction, Basic Concepts in Chemical Kinetics, Collection and Analysis ofRate Data, Nonelementary Homogeneous Reactions, Isothermal Reactor Design, Design for Multiple Reactions in Isothermal Reactors, Nonisothermal Reactors, Nonideal flow, Catalysis, Kinetics of Catalytic Reactions, Diffusion and Reactionin Porous Catalysts.
ChE331A	CHEMICAL REACTION ENGINEERING	3-0-0-0-9	Introduction: Definition of rate of reaction, types of reactors, industrial Ireactions and reactors. Basic Concepts in Chemical Kinetics: reaction rate constant, reaction order, elementary reactions and molecularity, reversible reactions, nonelementary reactions. Collection and Analysis of Rate Data: simple constant volume arid variable volume reaction systems, differential and integral methods of kinetic analysis, halflives, least squares analysis. Nouelementary Homogeneous Reactions: reaction mechanisms, pseudosteady state hypothesis, chain reactions, enzyme reactions Isothermal Reactor Design: batch reactor, mixed flow reactor, plug flow reactor; multiple reactor systems Design for Multiple Reactions in Isothermal Reactors: mass balances, selectivity and yield, parallel reactions, series reactions, complex reactions, best operating conditions for multiple reactions. Nonisothermal Reactors: energy balances for batch, mixed flow and plug flow reactors; adiabatic reactors, nonadiabatic reactors, multiple reactors with interstage cooling, multiple steady states. Nonideal flow: residence time distribution, tank in series model, dispersion model, applications to design H. Scott Fogler, Elements of Chemical Reaction Engineering, 4th edition, 2006, PrenticeHall of India, New Delhi.
ChE349A	UG PROJECT (UGP-I)	0-0-0-4-4	UG PROJECT (UGPI)
ChE352A	CHEMICAL PROCESS SIMULATION	1-0-2-0-5	Ideal and nonideal Value (Txy, Pxy plots, Azeotrope): Computation of 2+2VLE data (Temperature composition, Pressure composition plots) using (i) ideal mixture assumption

	LAB		and (ii) using various activity coefficient models such as VanLaar model, UNIFAC etc. Special emphasis on VLE of azeotropic mixtures. Examples: Benzene ethanol, Furfural water, benzene cyclohexane mixtures. Two film model for mass transfer between gas and liquid (e.g. C02 1+1absorption using K2C03 solution, NH3 absorption in dilute acid solution): Study of the absorption, reaction and diffusion processes in a contact reactor/bubble absorber/packed tower/plate column through the twofilm model. Formulation of the steady state problem in terms of differential equations for gas and liquid phase species using Fick's law, the gas liquid equilibrium relations, and reaction rate expressions. Effect of limiting diffusion and reaction steps. Numerical solution methods, such as CrankNicholson with Dirichlet and Neumann boundary conditions. Steady state concentration profiles with different combinations of rate parameters. **Course Reference**: 1. Introduction to chemical engineering computing by B. A. Finlayson; Indian edition by JohnWiley; 2. Chemical Process Modelling and Computer Simulation by A. K. Jana; PHI learning, 2008
ChE361	CHEMICAL PROCESS INDUSTRIES	3-1-0-1-4	Role of Chemical Engineer, Elementary Process Flow sheeting P & I diagrams, Inorganic Industry Fertilizers, Chlor alkalies, Natural Products Pulp & Paper, Oils, Soaps, Herbs, Petroleum & Petrochemicals: Refining/Crude Distillation; FCC, Catalytic Reforming; Alkylation, Amination, Hydrocracking, Aromatic Extraction, Plastics, Intermediates, dyes & paints, Pharmaceuticals, Environmental Pollution & Waste Treatment.
ChE362	BIOCHEMICAL ENGINEERING	3-0-0-1-4	Cell Structure and Cell Types, Chemicals of Life (RNA, DNA, enzymes etc.), Kinetics of Enzyme Reactions, Applied Enzyme Catalysis, Metabolic Stoichio metric and Energetics, Molecular Genetics and Control, Biomass Production, Transport Phenomena in Biosystems, Design and Analysis of Biological Reactors, Fermentors, Downstream Product Recovery and Purification, Interaction of Mixed Microbial Populations, Biological Wastewater Treatment.
ChE362A	BIOCHEMICAL ENGINEERING	3-0-0-0-9	Cell Structure and Cell Types, Chemicals of Life (RNA, DNA, enzymes etc.), Kinetics of Enzyme Reactions, Applied Enzyme Catalysis, Metabolic Stoichiometric and Energetics, Molecular Genetics and Control, Biomass Production, Transport Phenomena in Biosystems, Design and Analysis of Biological Reactors, Fermentors, Downstream Product Recovery and Purification, Interaction of Mixed Microbial Populations, Biological Wastewater Treatment.
ChE381	PROCESS DYNAMICS AND CONTROL	3-0-0-1-4	Introduction, Process models, Linearization, Laplace transforms. Process dynamics, Time delay, Feedback control, Instrumentation, Stability (Routh array & rootlocus), Frequency response analysis (Bode and Nyquist plots), Design of feedback controllers, High level control (Cascade, Smith predictor, feedforward, adaptive, inferential, ratio, override etc.), MIMO systems, Digital control.
ChE381A	PROCESS CONTROL	3-0-2-0-11	Introduction: to analog and digital feedback control; measurement devices Laplace transforms: of simple functions,

			derivatives, integrals, zero order holdZ transforms: of simple functions, improper sampling ANALOG: Modeling (time and Laplace domains) of simple and MIMO systems, linearization, deviations from steady state, systems with time delays. Dynamic behavior of first order systems: and their responses to Isimple, nonsinusoidal inputs. Dynamic behavior of second order systems: and their responses, overdamped and underdamped responses. Dynamic behavior of multicapacity: (interactive and noninteractive) systems, systems with time delays, inverse responses; Padeapproximations Frequency responses: Bode and Nyquist diagrams: first, second order systems, time delays, pure P, I and D controllers D.R. Coughanowr, Process Systems Analysis and Control, ed., McGraw Hill, New York, 1991.
ChE391	UNIT OPERATION LABORATORY-I	0-0-6-1-4	Fluid flow, Fluid particle systems, Thermodynamics Heat transfer, Mass transfer.
ChE391A	UNIT OPERATION LABORATORY -I	1-0-3-2-8	Safety, ethical guideline, error analysis, data presentation. Brief introduction to topics of experiments, relevance in industry Fluid flow, fluid particle system Thermodynamics Heat and mass transfer Demonstration lab Solid size reduction e.g. crushing and Igrinding, ball milling; Solid conveying e.g. pneumatic conveying, hydraulic conveying, Ibelt conveying. Analysis and testing of crude oil and petroleum products: 1Determination of octane number, cetane number, pour point, cloud point, smoke point **Course Reference**: 1. Unit Operation Laboratory Manual; 2. Unit Operations of Chemical Engineering; (7th Edition), by W.L. McCabe, J.C. Smith, and P. Harriott, McGraw Hill Publishing, 2005 (ISBN 0072848235); 3. Coulson and Richardson’s Chemical Engineering: Chemical Engineering Design
ChE398A	UG PROJECT II	0-0-9-0-9	UG PROJECT (UGP II)
ChE399A	CHEMICAL ENGINEERING COMMUNICATIO N SKILLS	0-0-0-2-2	chemical engineering communication skills
ChE452	COMPUTER APPLICATIONS IN CHEMICAL ENGG.	2-0-2-0-4	Artificial Intelligence and Networks in Chemical Engineering, Expert Systems (CONPHYDE, KBS) and Tools (KEE, ART), Artificial Neural Network, Learning and Training, Process Plant Diagnosis, Safety Analysis, Process Modelling, Interfacial properties, Fault Diagnosis and Trouble Shooting, Data Base Management and Qualitative Interpretation of Process Data, Simulation Packages, ASPEN PLUS, Batch Processing Packages (SUPERPRO), FLUENT
ChE453	CHEMICAL ENGINEERING DESIGN	3-1-0-1-4	Introduction to Design Process Development, process alternatives, Process Flow sheeting and simulation using ASPEN PLUS, Conceptual Process Synthesis,Conceptual design of reactors, pressure vessels, distillation/adsorption columns,storage vessels, Synthesis of Separation Trains, Cost Estimation & profitability analysis, Heat Exchange Network Analysis, Scaleup & pilot plant studies, HAZOP and Safety in

			design, Batch process Design for sequential processing usingSUPERPRO, Continuous plant design (group term projects).
ChE453A	CHEMICAL ENGINEERING DESIGN	3-0-2-0-11	Introduction to Design Process Development, process alternatives, Process Flow sheeting and simulation using ASPEN PLUS, Conceptual Process Synthesis,Conceptual design of reactors, pressure vessels, distillation/adsorption columns,storage vessels, Synthesis of Separation Trains, Cost Estimation & profitability analysis, Heat Exchange Network Analysis, Scaleup & pilot plant studies, HAZOP and Safety in design, Batch process Design for sequential processing using SUPERPRO, Continuous plant design (group term projects).
ChE463	ELECTRONIC POLYMERIC & CERAMIC MATERIALS & PROCESSING	3-0-0-1-4	Atomic structure, semiconductor materials, solar cells, Transistors and Process Sequence of Fabrication, Control of Microcontamination, Microlithography,Doping, Etching, Oxidation, Chemical Vapour Deposition and Reactor Design, Classification and Electrical, Mechanical Properties of Polymer, Polymer Catalysisand Molecular Chemistry, Flow Behaviour and Polymer Processing, Polymer Blendsand Composites, Applications of Polymers (Exchange Resin etc.), Ceramic RawMaterials and Characterization, Ceramic Processing Additives, Ceramic Beneficiation Process, Ceramic Forming Processes (Solgel, Casting etc.),Zeolites, Ceramic Drying, Surface Processing and Shaping.
ChE463A	ELECTRONIC POLYMERIC & CERAMIC MATERIALS & PROCESSING	3-0-0-0-9	Atomic structure, semiconductor materials, solar cells, Transistors and Process Sequence of Fabrication, Control of Microcontamination, Microlithography, Doping, Etching, Oxidation, Chemical Vapour Deposition and Reactor Design,Classification and Electrical, Mechanical Properties of Polymer, Polymer Catalysisand Molecular Chemistry, Flow Behaviour and Polymer Processing, Polymer Blendsand Composites, Applications of Polymers (Exchange Resin etc.), Ceramic Raw Materials and Characterization, Ceramic Processing Additives, Ceramic Beneficiation Process, Ceramic Forming Processes (Solgel, Casting etc.),Zeolites, Ceramic Drying, Surface Processing and Shaping.
ChE492	UNIT OPERATION LAB II	0-0-6--4	Mass Transfer, Heat transfer, chemical reactors, Computer aided data acquisitionand online analysis, Process dynamics and control.
ChE492A	UNIT OPERATIONS AND PROCESS CONTROL LABORATORY	1-0-3-2-8	Mass Transfer, Heat transfer, chemical reactors, Computer aided data acquisitionand online analysis, Process dynamics and control.
ChE494	SUMMER IN-PLANT TRAINING	0-0-4--2	A written report and an oral presentation/interview after successful completion of an 8.week industrial inplant training with a chemical industry.
ChE494A	SUMMER IN-PLANT TRAINING	0-0-5-0-5	A written report and an oral resentation/interview after successful completionof an 8week industrial inplant training with a chemical industry.
ChE495	PROJECT-I	0-0-8-0-4	Student will work on design/research projects to carry out theoretical/experimentalwork on problems in chemical

			engineering as assigned by the project advisor.
ChE496	PROJECT II	-0-8--4	PROJECT II
ChE497A	UNDER GRADUATE PROJECT-III	0-0-0-0-9	UG PROJECT (UGPII)
ChE600	RESEARCH METHODS & SKILLS	3-0-0--4	Definition and nature of research, Motivation for research, different types and styles of research in sciences, role of serendipity, scientific temperament, Is science necessary? Working of some of the great minds from all walks of life scientists, artists, writers, etc. Tools for thinking, critical and positive thinking, creativity and innovation, mind mapping; Development of problem- solving skills, scaling and orders of magnitude analysis, role of simple models in thinking andin developing an understanding. Scientific and critical reasoning skills, art of reading and understanding scientific papers and critical evaluation of the underlying premises and assumptions, literature reviews. Professional attitudesand goals, concept of excellence, ethics in science and engineering, some famousfrauds in science. Scientific communication, Organisation of ideas, writingscientific papers, reports and thesis; Making scientific presentations at conferences; Presenting popular lectures to semitechnical and or/nontechnical audience/participating in public debates on scientific issues.
ChE601	FUNDAMENTAL S OF CHEMICAL ENGINEERING -I	3-0-0-0-4	Mathematics modulue: 1. Linear algebra: Basics (2lectures; Chap. 3 ofMLB) 2. Linear algebra: Numerical methods (3 lectures; Chap. 1 of SKG) 3. Nonlinear algebraic equations: Numerical solution, including multivariable Newton Raphson method (4 lectures, Chap. 3 of SKG) 4. Ordinary differential equations: Basics (2lectures; Chap. 8 ofMLB) 5. Numerical solution of ODEs Initial value problems (2 lectures, Chap. 5 of SKG) 6. Numerical solution of ODEs Boundary value problems (2 lectures, Chap. 6 of SKG) 7. Probability and statistics (5 lectures; Chap. 16 of MLB) Transport Phenomena module: 8. Introduction to momentum transport (Lecture; Chap. 1 of BSL) 9. Shell balances for 1D momentum transport (2lectures; Chap. 2 ofBSL) 10. NavierStokes equations (2lectures; Chap. 3 ofBSL) 11. Unsteady and 2D momentum transfer (3 lectures ofBSL).12. Introduction to heat transfer (1 lecture; Chap. 9 ofBSL) 13. Shell balances for 1D heat transfer (2lectures; Chap. 10 ofBSL) 14. Temperature distributions with more than one independent variable (3 lectures; Chap. 12 ofBSL) 15. Introduction to mass transfer (Lecture; Chap. 17 ofBSL). 16. Diffusion and mass transfer in laminar flow (3 lectures; Chap. 18 ofBSL) 17. Mass transfer with more than one independent variable (2 lectures; Chap. 20 of BSL) **Course Reference**: 1. M. L. Boas (MLB), Mathema tical Methods in the Physical Sciences (Second Edition), John Wiley & Sons (Indian edition); 2. S. K. Gupta (SKG) Numerical Methods for Engineers, New Age International; 3. R. B. Bird, W. E. Stewart, E. L. Lightfoot (BSL), Transport Phenomena (Second Edition)John Wiley & Sons (Indian Edition).

ChE601A	FUNDAMENTALS OF CHEMICAL ENGINEERING -I	3-0-0-0-9	Mathematics modulue: 1. Linear algebra: Basics (2lectures; Chap. 3 ofMLB); 2. Linear algebra: Numerical methods (3 lectures; Chap. 1 of SKG); 3. Nonlinear algebraic equations: Numerical solution, including multivariable Newton Raphson method (4 lectures, Chap. 3 of SKG); 4. Ordinary differential equations: Basics (2lectures; Chap. 8 ofMLB); 5. Numerical solution of ODEs Initial value problems (2 lectures, Chap. 5 of SKG); 6. Numerical solution of ODEs Boundary value problems (2 lectures, ChaP.. 6 of SKG); 7. Probability and statistics (5 lectures; Chap. 16 of MLB)Transport Phenomena module; 8. Introduction to momentum transport (!lecture; Chap. 1 ofBSL); 9. Shell balances for 1D momentum transport (2lectures; Chap. 2 ofBSL); 10. NavierStokes equations (2lectures; Chap. 3 ofBSL); 11. Unsteady and 2D momentum transfer (3 lectures ofBSL); 12. Introduction to heat transfer (1 lecture; Chap. 9 ofBSL); 13. Shell balances for 1D heat transfer (2lectures; Chap. 10 ofBSL); 14. Temperature distributions with more than one independent variable (3 lectures; Chap. 12 ofBSL); 15. Introduction to mass transfer (!lecture; Chap. 17 ofBSL); 16. Diffusion and mass transfer in laminar flow (3 lectures; Chap. 18 ofBSL); 17. Mass transfer with more than one independent variable (2 lectures; Chap. 20 of BSL) **Course Reference**: 1. M. L. Boas (MLB), Mathematical Methods in the Physical Sciences (Second Edition),John Wiley & Sons (Indian edition); 2. S. K. Gupta (SKG) Numerical Methods for Engineers, New Age International; 3. R. B. Bird, W. E. Stewart, E. L. Lightfoot (BSL), Transport Phenomena (Second Edition)John Wiley & Sons (Indian Edition).
ChE602	FUNDAMENTALS OF CHEMICAL ENGINEERING - II	3-0-0-0-4	Module on Thermodynamics:1. Review of 1st and 2nd Law of Thermodynamics (including applications) (2lectures); 2. PVT relations of pure fluids (cubic EOS, generalized correlations, compressibility factor) (2 lectures); 3. Thermodynamic properties of pure fluids (Single phase systems: Thermodynamic potentials, Maxwell's relations, residual properties. Two phase systems: Clapeyron equation, Phasediagrams. Generalized property correlations for gases) (3 lectures); 4. Multicomponent Mixtures: Partial molar properties, Gibbs Duhem equation, Chemical potential for phase equilibria, Fugacity and fugacity coefficient. The ideal solution andexcess molar properties. Activity coefficients and models (Margules, NRTL, Wilson, UNIQUAC) (3 lectures); 5. Vapor Liquid Equilibrium: multicomponent phase envelopes, gammaphi formulation, dewpoint, bubble point and flash calculations, modified Raoult's law, Henry's law (4lectures); 6. Thermodynamic properties and VLE from cubic EOS (2 lectures); 7. Other types of phase equilibria: LLE, VLLE, SLE (1 lecture); 8. Heat of adsorption, multicomponent adsorption equilibrium (1 lectures); 9. Chemical reaction equilibrium (2 lectures)Module on Reaction Engineering:10. Idealization in chemical reaction engineering (1 lecture; Chap. 1 ofHSF); 11. Steady and unsteady state operation in idealized reactors (3 lectures; Chap. 4 of HSF); 12. Multiple reactions (2 lectures; Chap. 6 ofHSF); 13. Nonelementary reaction kinetics (3

			lectures; Chap. 7 ofHSF); 14. Modeling of Catalytic reaction kinetics (3 lectures); 15. External diffusion effects on heterogeneous reactions (2lectures; Chap. 11 ofHSF); 16. Diffusion and reaction in porous catalysts (4lectures; Chap. 12 ofHSF); 17. Design of fixed bed reactors (2 lectures). **Course Reference**:1. H. Scott Fogler (HSF) Elements of Chemical Reaction Engineering, Prentice Hall (India); 2. S. I. Sandler (SIS) Chemical and Biological Engineering Thermodynamics, John Wiley (Indian Edition).
ChE602A	FUNDAMENTALS OF CHEMICAL ENGINEERING - II	3-0-0-0-9	Module on Thermodynamics: 1. Review of 1st and 2nd Law of Thermodynamics (including applications) (2lectures); 2. PVT relations of pure fluids (cubic EOS, generalized correlations, compressibility factor) (2 lectures); 3. Thermodynamic properties of pure fluids (Single phase systems: Thermodynamic potentials, Maxwell's relations, residual properties. Two phase systems: Clapeyron equation, Phasediagrams. Generalized property correlations for gases) (3 lectures); 4. Multicomponent Mixtures: Partial molar properties, Gibbs Duhem equation, Chemical potential for phase equilibria, Fugacity and fugacity coefficient. The ideal solution andexcess molar properties. Activity coefficients and models (Margules, NRTL, Wilson, UNIQUAC) (3 lectures); 5. Vapor Liquid Equilibrium: multicomponent phase envelopes, gammaphi formulation, dewpoint, bubble point and flash calculations, modified Raoult's law, Henry's law (4lectures); 6. Thermodynamic properties and VLE from cubic EOS (2 lectures); 7. Other types of phase equilibria: LLE, VLLE, SLE (1 lecture); 8. Heat of adsorption, multicomponent adsorption equilibrium (1 lectures); 9. Chemical reaction equilibrium (2 lectures)Module on Reaction Engineering; 10. Idealization in chemical reaction engineering (1 lecture; Chap. 1 ofHSF); 11. Steady and unsteady state operation in idealized reactors (3 lectures; Chap. 4 of HSF);12. Multiple reactions (2 lectures; Chap. 6 ofHSF); 13. Nonelementary reaction kinetics (3 lectures; Chap. 7 ofHSF); 14. Modeling of Catalytic reaction kinetics (3 lectures); 15. External diffusion effects on heterogeneous reactions (2lectures; Chap. 11 ofHSF); 16. Diffusion and reaction in porous catalysts (4lectures; Chap. 12 ofHSF); 17. Design of fixed bed reactors (2 lectures). **Course Reference**: 1. H. Scott Fogler (HSF) Elements of Chemical Reaction Engineering, Prentice Hall (India); 2. S. I. Sandler (SIS) Chemical and Biological Engineering Thermodynamics, John Wiley (Indian Edition).
ChE603A	MATHEMATICAL MODEL IN BIOLOGY	3-0-0-0-9	Continuous Population Models for single species: Continuous growth models, Insect outbreak model, Delay models, Linear analysis of Delay population models, Delay models in Physiology, Harvesting a single natural population, Population model with Age distribution. Models for Interacting Populations: predator prey models: LotkaVolterra systems, Complexity and stability, Realistic predatorprey models, Analysis of a predatorPrey model with limit cycle periodic behaviour: Parameter domains of stability, Competition models: Competitive exclusion principle, Mutualism or Symbiosis, General models and cautionary remarks,

			Threshold Phenomena. Reaction Kinetics: Enzyme kinetics: Basic enzyme reaction, Transient time estimates and nondimensionalisation, Michaelis Menten quasisteady state analysis, Suicide substrate kinetics, Cooperative phenomena, Autocatalysis, Activations and Inhibition, Multiple steady state, Mushrooms and Isolas. Biological Oscillators and Switches: Motivation, brief history and background, Feedback control mechanisms, Oscillators and switches with two or more species: General qualitative results, Simple two species oscillators: Parameter domain determination for oscillations, Hodgkin Huxley theory of nerve membranes: FitzHugh Nagumo model. **Course Reference**: 1. Mathematical Biology I: An Introduction, Author: J.D. Murray, Publisher Springer. 2. Mathematical Models in Biology: AuthorLeah Edelstein, Keshet, Publisher: SIAM 07-OCT-2015
ChE611	TRANSPORT PHENOMENA	3-0-0--4	Kinematics, Transport theorem, constitutive relations, Equations of motion and their solutions, Boundary layer theory, Turbulence; Energy equation and its exact solutions, Continuity equation for multicomponent systems, constitutive relations, Interphase transport of momentum, energy and mass and macroscopic balances.
ChE611A	TRANSPORT PHENOMENA	3-0-0-0-9	Kinematics, Transport theorem, constitutive relations, Equations of motion andtheir solutions, Boundary layer theory, Turbulence; Energy equation and its exactsolutions, Continuity equation for multicomponent systems, constitutive relations, Interphase transport of momentum, energy and mass and macroscopic balances. Course Reference :?
ChE612	SCIENCE & TECHNOLOGY OF DRUGS	3-0-0-0-4	1. Physical Chemical properties and biological activity; 2. Molecular orbifal theory in drug design; 3. Structural features and pharmacological activity; 4. Drug metabolism and procedure of tailoring drugs; 5. Receptor site theory and substitution therapy; 6. CNS depressants, sedativehypnotic d1ugs and their synthesis; 7. CNS stimulants and their synthesis; 8. Chemotherapy and oncology. Synthesis of drugs, mechanism of action and procedure treatment; 9. Drugs affecting sugar and diabetes mellitus. Synthesis of drugs and procedure treatment; 10. Sex hormones and oral contraceptives; Immunity and al ergies. HIV and AIDS and procedure treatment. Psychotic and related drugs **Course Reference**:1. Harrison's Principles of Internal Medicine, 15th Ed, McGraw Hill, N.Y., 2001; 2. Goodman and Gillman's The Pharmacological Basis of Therapeutics, gth Ed, McGraw Hill, N.Y., 1992; 3.W.O. Foye, Principles of Medicinal Chemistry, Lea and Febiger, Philadelphia,1974.
ChE613	THE STRUCTURE & RHEOLOGY OF COMPLEX FLUIDS	3-0-0-0-4	Introduction to Complex Fluids (CF) and Soft Condensed Matter (SCM) (2 hours) Basic Forces, Energies and Timescales in CF and SCM. (5 hours) Excluded volume interactions, Van Der Waals interactions, Electrostatic interactions, Hydmgen bonding. Relaxation phenomena in CS and SCM. Fundamentals of Rheology (6 hours) Different types of flow fields, linear and nonlinear Viscoelasticity, Kinematics and stress, Boltzmann Superposition Principle.Various

			Characterization Techniques (6 hours) Microscopy, Light scattering techniques, Dielectric spectroscopy, Rheaoptics Polymers (8 hours) Rheology of dilute polymer solutions: Elementary molecular theories, linear and nonlinear rheology. Rheology of entangled polymers: Reptation theories, Transient network formulations Colloidal dispersions: (6 hours) Rheological behavior of dilute and concentrated suspensions of isotropic particles, nonspherical particles, particles in viscoelastic media Glassy Systems: (6 hours) Introduction to glass transition. Rheology of amorphous polymers, very concentrated suspensions, emulsions, foams, colloidal gels. Relaxation behavior, yield stress, thixotropic behavior, ageing and rejuvenation. **Course Reference**: 1.Ronald G. Larson, The Structure and Rheology of Complex Fluids, Oxford University Press(1998); 2.Richard A.L. Jones, Soft Condensed Matter, Oxford University Press (2002); 3.Ch. W. Macosko, Rheology: Principles, Measurements, and Applications, WileyVCH (1994); 4. H. A. Barnes, J. F. Hutton, K. Walters, An introduction to rheology, Elsevier (1989); 5. Montgomery T. Shaw and William J. MacKnight, Introduction to Polymer Viscoelasticity,Wiley Interscience; (2005)
ChE613A	THE STRUCTURE & RHEOLOGY OF COMPLEX FLUIDS	3-0-0-0-9	Introduction to Complex Fluids (CF) and Soft Condensed Matter (SCM) (2 hours) Basic Forces, Energies and Timescales in CF and SCM. (5 hours) Excluded volume interactions, Van Der Waals interactions, Electrostatic interactions, Hydmgen bonding. Relaxation phenomena in CS and SCM.Fundamentals of Rheology (6 hours) Different types of flow fields, linear and nonlinear Viscoelasticity, Kinematics and stress, Boltzmann Superposition Principle.Various Characterization Techniques (6 hours) Microscopy, Light scattering techniques, Dielectric spectroscopy, RheaopticsPolymers (8 hours) Rheology of dilute polymer solutions: Elementary molecular theories, linear and nonlinear rheology. Rheology of entangled polymers: Reptation theories, Transient network formulations Colloidal dispersions: (6 hours) Rheological behavior of dilute and concentrated suspensions of isotropic particles, nonspherical particles, particles in viscoelastic media Glassy Systems: (6 hours) Introduction to glass transition. Rheology of amorphous polymers, very concentrated suspensions, emulsions, foams, colloidal gels. Relaxation behavior, yield stres, thixotropic behavior, ageing and rejuvenation. **Course Reference**: 1. Ronald G. Larson, The Structure and Rheology of Complex Fluids, Oxford University Press (1998); 2. Richard A.L. Jones, Soft Condensed Matter, Oxford University Press (2002); 3.Ch. W. Macosko, Rheology: Principles, Measurements, and Applications, WileyVCH (1994); 4. H. A. Barnes, J. F. Hutton, K. Walters, An introduction to rheology, Elsevier (1989). Montgomery T. Shaw and William J. MacKnight, Introduction to Polymer Viscoelasticity, Wiley Interscience; (2005)

ChE617	NUCLEAR CHEMICAL ENGINEERING	3-0-0-0-4	Lectures Chemical Engineering Aspects of Nuclear Power Uranium, Zirconium & Thorium: Concentration, Purification and Production Extraction ofNuclear Metals: Principles, Theory & Equipment; Solvent Extraction, Ionic Liquid & Membrane Processes Separation of Nuclear Reactor Products: Redox, Urex I Purex, Thorex ,TTA chelation, Precipitation, Ion Exchange & Fluoride Distillation with simulation a Separation of Light Isotopes: Principles; Distillation & Electrolysis of Water, Electrolysis & Steam Hydrogen/Deuterium Exchange Processes 6Separation of Heavy Isotopes : Principles; Mass, Gas & Thermal Diffusion Processes, Nuclear Hydrogen Production : SulfurIodine Cycle, Hybrid Sulfur Route, High Temperature Electrolysis; with simulation bNuclear heat for coal liquefaction & gasification; with simulation **Course Reference**: 1. Nuclear Chemical Engineering by Benedict, Pigford & Han, 2nd edition, McGrawHill 1981; 2. General Reading: Solvent Extraction Principles and Practice, ed by Rydberg, Cox, Musikas & Choppin ,211d ed., Marcel Dekker 2004; 3. International Atomic Energy Agency Publications Relevant research papers from AIChEJ, Ind. Eng. Chem. Res., Nuc.Eng.& Des.SIMULATOR: ASPEN PLUS based simulations for a) Separation Flowsheets b) SICycle, Hybrid Sulfur Route c) Coal Liquefaction/gasification
ChE618	NEW SEPARATION PROCESSES	3-0-0--4	Separation Factors for Rate Governed Separation Processes, Membrane Characterization; Reverse Osmosis: Models of Solvent and Solute Transport, Concentration Polarization; Ultrafiltration: Types of Transport through UFMembranes, Fouling and Concentration Polarization in UF, Osmaotic Pressure Model utization; Diafiltration: Process Design; Dialysis: Solute Transport analysis of dialyzer operation, Mode of Dialysis; Electrodialysis: Types of Electro dialysis Ion Transport Fundamentals, Concept of Limiting Current Density, Concentration Polarization; Liquid Membrane; Permeation of Gases through Membranes and Pervaporation.
ChE618A	NEW SEPARATION PROCESSES	3-0-0-0-9	Separation Factors for Rate Governed Separation Processes, Membrane Characterization; Reverse Osmosis: Models of Solvent and Solute Transport, Concentration Polarization; Ultrafiltration: Types of Transport through UF Membranes, Fouling and Concentration Polarization in UF, Osmaotic Pressure Model utization; Diafiltration: Process Design; Dialysis: Solute Transport analysisof dialyzer operation, Mode of Dialysis; Electrodialysis: Types of Electro dialysis Ion Transport Fundamentals, Concept of Limiting Current Density, Concentration Polarization; Liquid Membrane; Permeation of Gases through Membranes and Pervaporation.
ChE621	THERMODYNAMICS	3-0-0-0-4	Postulational Thermodynamics: Postulates; Equilibrium criteria; Gibbs Duhemrelation; Energy minimum principle;

			Thermodynamic potentials; Stability andphase Transition. Statistical Thermodynamics: Statistical mechanics of ensembles Estimation of Thermodynamic properties in Ideal gases, Estimation of equilibrium constant in reacting systems.
ChE621A	THERMODYNAMICS	3-0-0-0-9	Postulational Thermodynamics: Postulates; Equilibrium criteria; Gibbs Duhemrelation; Energy minimum principle; Thermodynamic potentials; Stability andphase Transition. Statistical Thermodynamics: Statistical mechanics of ensemblesEstimation of Thermodynamic properties in Ideal gases, Estimation of equilibrium constant in reacting systems.
ChE622	INTRODUCTION TO MOLECULAR SIMULATIONS	3-0-0--4	Theory methods, and application of molecular simulation. Elementary statistical mechanics. Molecular modeling. Basic Monte Carlo and molecular dynamics techniques and ensemble averaging. Evaluation of free energies, phase equilibria, interfacial properties, and transport and rate coefficients. Applications to simpleand complex fluids and solids. Commercial simulation software.
ChE622A	INTRODUCTION TO MOLECULAR SIMULATIONS	3-0-0-0-9	Theory methods, and application of molecular simulation. Elementary satisticalmechanics. Molecular modeling. Basic Monte Carlo and molecular dynamicstechniques and ensemble averaging. Evaluation of free energies, phase equilibria, interfacial properties, and transport and rate coefficients. Applications to simple and complex fluids and solids. Commercial simulation software.
ChE623	THERMODYNAMICS OF FLUIDS AND FLUID MIXTURES	3-0-0--4	Classical thermodynamics of phase equilibria: Thermodynamic properties from volumetric data: Nature of intermolecular forces, Theory of corresponding states; Fugacities in gas mixtures and liquid solutions; gas solubilities; High pressure equilibria.
ChE623A	THERMODYNAMICS OF FLUIDS AND FLUID MIXTURES	3-0-0-0-9	Classical thermodynamics of phase equilibria: Thermodynamic properties from volumetric data: Nature of intermolecular forces, Theory of corresponding states; Fugacities in gas mixtures and liquid solutions; gas solubilities; High pressure equilibria.
ChE626A	PRACTICAL INTRO. TO QUANTUM MECHANICAL METHODS FOR SCIENTISTS & ENGINEERS		Summary of classical mechanics: conservation laws, Hamiltonian and Lagrangian formulation; The need for quantum mechanics; Basic concepts: physical observables and operators, expectation values, Heisenbergr’s uncertainty principle, Schrodinger’s equation; The many-body Hamiltonian, Born-Oppenheimer ¨ approximation, variational principle, the concept of potential energy surface; What makes electronic structure difficult; Hartree-Fock (HF) approach: restricted and unrestricted method, and their comparison with experiments; Localized and plane-wave basis sets; Pseudopotentials; Density functional theory (DFT): Hohenberg-Kohn theorems, Kohn-Sham formulation; Exchange and correlations: LDA and GGA approximations; Pure and hybrid DFT functionals; Tricks for self-consistent solution of the Kohn-Sham system: mixing and diagonalization techniques; Failures and

			successes of DFT: vander Waal's correction and DFT+U approach; Configuration interaction and Miller-Plesset perturbation theory; Applications of quantum-mechanical methods in engineering and sciences; Specialized topics (if time permits): Ab initio molecular dynamics (Born-Oppenheimer and Car-Parrinello), ring-polymer molecular dynamics.
ChE631	CHEMICAL REACTION ENGINEERING	3-0-0--4	Behaviour of chemical reactions; Behaviour of chemical reactors: ideal and nonideal flow, nonisothermal reactor performance, reactor stability; Heterogeneous reactions: interphase and intraphase heat and mass transfer effects; Fluid Solid noncatalytic reactions; Heterogeneous catalytic reactions.
ChE631A	CHEMICAL REACTION ENGINEERING	3-0-0-0-9	Behaviour of chemical reactions; Behaviour of chemical reactors: ideal and nonideal flow, nonisothermal reactor performance, reactor stability; Heterogeneous reactions: interphase and intraphase heat and mass transfer effects; Fluid Solid noncatalytic reactions; Heterogeneous catalytic reactions.
ChE632	ANALYSIS AND DESIGN OF MULTIPHASE REACTORS	3-0-0--4	Noncatalytic two phase reactions Introduction; review of physical mass transfer; different regimes of mass transfer with chemical reaction. General theory of mass transfer with chemical reaction; global rates ofreaction for different regimes. Design of different types of gas-liquid reactors. Penetration model for mass transfer, population balance models and particulate systems. Solidcatalysed gas-liquid reactionsTypes of multiphase reactors and their applications :1. Determination of global rates for multiphase reactions; 2. Experimental methods for evaluation of parameters; 3. Mechanically agitated slurry reactors: hydrodynamics, mass transfer, heat transfer and modelling; 4. Bubble column reactors: hydrodynamics, heat transfer,mass transfer and modelling; 5. Trickle bed reactors: hydrodynamics, heat transfer, mass transfer, effectiveness factor, and modelling; 6.Monolith reactors: preparation, hydrodynamics mass transfer and modelling **Course Reference**: 1. Cybulski, A. and Moulijn, J.A.,2006, Structured Catalysts and Reactors, 2nd edition; 2. Froment, G.F. and Bischoff, K.B., 1990, Chemical Reactor Analysis and Design, Wiley, New York; 3. Gianetto, A. and Sylveston, P.L (editors) 1986, Multiphase Chemical Reactors. Theory, Design, Scaleup, Hemisphere Publishing Co., New York; 4. Ramachandran, P.A. and Chaudhari, R.V. I983, Three Phase Catalytic Reactors, Gordonand Breach, New York, USA; 5. Sharma, M.M. and Doraiswamy, L.K, 1984, Heterogeneous Reactions: Volume II, Wiley, New York; 6. Trambouze, P. and Euzen, J.P., 2004, Chemical Reactors. From design to operation, Technip, Paris.In addition, reading assignments will be given from recent journal publications
ChE633	PRINCIPLES OF	3-0-0--4	Adsorption; Energetics; Isotherms and Rates:

	HETEROGENEOUS CATALYSIS		Experimental aspects of adsorption and allied phenomena on catalyst surfaces; Pore structure and surface are aestimation and their significance; Important catalysts, Promoters and Carriers; Mechanisms of some typical heterogeneous catalytic reactions, e.g., Oxidation.
ChE633A	PRINCIPLES OF HETEROGENEOUS CATALYSIS	3-0-0-0-9	Adsorption; Energetics; Isotherms and Rates: Experimental aspects of adsorption and allied phenomena on catalyst surfaces; Pore structure and surface are aestimation and their significance; Important catalysts, Promoters and Carriers; Mechanisms of some typical heterogeneous catalytic reactions, e.g., Oxidation.
ChE641	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	3-0-0--4	Modelling, Vector Spaces, Matrices, Linear Operators, Initial Value Problem, Partial Differential Equation, Sturm Louiville Theory, Separation of Variables, Greens Functions, Transform Techniques, Nonlinear Equations, Continuation Methods, Bifurcation and Chaos.
ChE641A	MATHEMATICAL METHODS IN CHEMICAL ENGINEERING	3-0-0-0-9	Modelling, Vector Spaces, Matrices, Linear Operators, Initial Value Problem, Partial Differential Equation, Sturm Louiville Theory, Separation of Variables, Greens Functions, Transform Techniques, Nonlinear Equations, Continuation Methods, Bifurcation and Chaos.
ChE642	NUMERICAL METHODS IN CHEMICAL ENGINEERING	3-0-0--4	Systems of Linear and NonLinear Algebraic Equations: Successive Substitution, Newton Raphson, Eigenvalues and Eigenvectors of Matrices, Interpolation, Solutions of ODEs (IVP): Runge Kutta, Multistep Methods, Gears algorithm Stiffness and Stability of algorithms, ODE (BVPs) and PDEs: Finite Difference, Finite Elements, Shooting Methods.
ChE642A	NUMERICAL METHODS IN CHEMICAL ENGINEERING	3-0-0-0-9	Systems of Linear and NonLinear Algebraic Equations: Successive Substitution, Newton Raphson, Eigenvalues and Eigen vectors of Matrices, Interpolation, Solutions of ODEs (IVP): Runge Kutta, Multistep Methods, Gears algorithm, Stiffness and Stability of algorithms, ODE (BVPs) and PDEs: Finite Difference, Finite Elements, Shooting Methods.
ChE644	CFD OF MULTIPHASE REACTORS	3-0-0--4	Mathematical Modeling: conservation equations; dimensionless Lectures numbers; boundary conditions; Numerical solution of model equations: Finite volume method discretization schemes; Colocated and staggered grid; Boundary conditions, also for symmetric and periodic flows; pressure velocity coupling; pressurecorrection equation based solution method; under relaxation factors; Algorithms SIMPLE/R, QUICK/Superbee; convergence and error analysis; 5Turbulent flow:Reynolds Averaged Navier Stokes (RANS) equations eddy viscosity models; kE models; Multiphase Flow:Approaches: Eulerian & Volume of fluid (VOF); dispersed multiphase flows ;flow through porous media; dense and dilute suspensions; solids pressure; granular temperature;.drag coefficients for single and multiphase systems; interphase heat & mass transfer correlationsfor GL,GS, LS, GLS flows. 5. Reactive flow processes: reactive mixing micro, macro & turbulent;

			RANS based models: species transport; homogeneous and heterogeneous reactions: volumetric, wall surface & particle surface reactions. Reactor Flow modeling: Reactor types: stirred tank, bubble column, fixed bed, fluidized bed.; Reactor Internals: impellers, baffles, spargers, heating & cooling coils, distributors & mixing grids.; population balance models: coalescence & breakage models for bubble/drop size distributions. Solid phase characterization based on solid pressure, granular temperature,particle size distribution, dense and dilute suspensions.
ChE645	MODELLING AND SIMULATION IN CHEMICAL ENGINEERING	3-0-0--4	Mathematical Model and its Necessity: Model Development principles: Synthesis of submodels, Experimental facts, Hypothesis, Dimensional Analysis, Scaling, Reduction of equations. Classification of Models: Deterministic and stochastic Example from thermal diffusion, Lumped and Distributed parameter Example from stirred tank andplug flow, Additional examples from transport processes and chemical kinetics. Modelling and Simulation Techniques: Length and time scale analysis in multiscale systems, Population balance models Fundamentals, Examples from Crystallization, coagulation, Microbial population, Monte Carlo methods Basicsof Random No. and Probabbility distribution, Time and event driven methods,Stochastic models Poisson Process, Markov process, Birthdeath process, Nonlineardynamics and Chaos Principles, Application in mixing, reaction, stirred tank, fludized bed, Fractal models Diffusion and reaction limited growth, Aggregate structure.Solution and analysis of results: Parameter estimation, Asymptotes, Moments,Phase plane, Time series.
ChE652	OPTIMIZATION	3-0-0--4	Mathematical formulation of optimization problems; single variable problems: search techniques; Multivariable problems without constraints: direct methods, first and second order methods; Multivariable problems with constraints: Calculusof variations; Pontryagins maximum principle; Dynamic Programming.
ChE652A	OPTIMIZATION	3-0-0-0-9	Mathematical formulation of optimization problems; single variable problems: search techniques; Multivariable problems without constraints: direct methods, first and second order methods; Multivariable problems with constraints: Calculusof variations; Pontryagins maximum principle; Dynamic Programming.
ChE654	PROCESS ENGINEERING	3-0-0--4	Introduction to the elements of process design, process development, process evaluation; flow sheeting; Pilot plant; Optimization and economic considerations, process design engineering, project engineering, practical considerations; safety considerations and successful plant operations, case studies
ChE659	PROCESS ENGG. PRINCIPLES IN MICRO.	3-0-0-0-4	This course provides an insight into the process engineering principles in microelectronic fabrication. The transport processes, reaction kinetics and reactor design

	FABRICATION		aspects of the following topics will be covered silicon crystal growth, oxidation, ion implantation, chemical and physical vapor deposition, rapid thermal processing, epitaxy, lithography, plasma processing (deposition and etch), electrochemical deposition andchemical mechanical planarization. Also, the cleanliness and purity in processenvironment (e.g. filtration, mechanisms of particulate deposition and removal onsurfaces) will be covered. **Course Reference**:1. Stanley Middleman, Arthur Hochberg, process Engineering Analysis inSemiconductor Device Fabrication, McGraw Hill, 1st Ed, 1993; 2. Stephen A. Campbell, The Science and Engineering of Microelectronic Fabrication, Oxford University Press, 2nd Ed, 2001; 3. Peter VanZant; Microchip Fabrication, McGraw Hill, 5th Ed, 2004.(Students likely to take the course: Chemical Engineering, Electrical Engineering, Metallurgical and Materials Engineering, Materials Science Program.
ChE659A	PROCESS ENGG. PRINCIPLES IN MICRO. FABRICATION	3-0-0-0-9	This course provides an insight into the process engineering principles in microelectronic fabrication. The transport processes, reaction kinetics and reactor design aspects of the following topics will be covered silicon crystal growth, oxidation, ion implantation, chemical and physical vapor deposition, rapid thermal processing, epitaxy, lithography, plasma processing (deposition and etch), electrochemical deposition andchemical mechanical planarization. Also, the cleanliness and purity in process environment (e.g. filtration, mechanisms of particulate deposition and removal onsurfaces) will be covered. **Course Reference**: 1. Stanley Middleman, Arthur Hochberg, Process Engineering Analysis inSemiconductor Device Fabrication; McGraw Hill, 1st Ed, 1993; 2. Stephen A. Campbell; The Science and Engineering of Microelectronic Fabrication, Oxford University Press, 2nd Ed, 2001. 3. Peter VanZant; Microchip Fabrication, McGraw Hill, 5th Ed, 2004. (Students likely to take the course): Chemical Engineering, Electrical Engineering, Metallurgical and Materials Engineering, Materials Science Program.
ChE661	ANALYTICAL & MATERIAL CHARACTERIZATIO N TECHNIQUES OF ENGINEERS	3-0-0-0-4	1. Introduction: Various terms in measurement. Accuracy, precision, selectivity, limit of detection, sensitivity, response time, reliability, signal/noise and sources of noise/errors (2 lectures); 2. Chemical analysis of materials: Techniques for the analysis of structure, chemical composition and trace impurities in materials. Xray photoelectron spectroscopy (XPS), mass spectrometry (MS) and other spectroscopy techniques at atomic and molecular levels (12lectures); 3. Microscopy and diffraction: Optical microscopy, Scanning probe microscopy, Electron microscopy (both SEM and TEM), Xray Diffraction. Theoretical and practical aspects of the microscopy and diffraction techniques will be introduced.

			Imaging using scanning tunneling microscope (STM) will also be considered (12 lectures); 4. Thermal analysis: Applications of thermal analysis. Various techniques such as TGA, DSC, DTA, and TMA will be covered (6 lectures). 21-SEP-2014
ChE661A	ANALYTICAL & MATERIAL CHARACTERIZATIO N TECHNIQUES OF ENGINEERS	3-0-0-0-9	1. Introduction: Various terms in measurement. Accuracy, precision, selectivity, limit of detection, sensitivity, response time, reliability, signal/noise and sources of noise/errors (2 lectures); 2. Chemical analysis of materials: Techniques for the analysis of structure, chemical composition and trace impurities in materials. Xray photoelectron spectroscopy (XPS), mass spectrometry (MS) and other spectroscopy techniques at atomic and molecular levels (12lectures); 3. Microscopy and diffraction: Optical microscopy, Scanning probe microscopy, Electron microscopy (both SEM and TEM), Xray Diffraction. Theoretical and practical aspects of the microscopy and diffraction techniques will be introduced. Imaging using scanning tunneling microscope (STM) will also be considered (12 lectures); 4. Thermal analysis: Applications of thermal analysis. Various techniques such as TGA, DSC, DTA, and TMA will be covered (6 lectures).
ChE662	PETROLEUM REFINERY ENGINEERING	3-0-0-0-4	Petroleum refining in India; refinery tests and crude oil evaluation; crude distillation column design; Delayed Coking; Catalytic cracking; Catalytic reforming; Catalytic isomerization; Alkylation; Polymerization; Hydrocracking; Hydrotreating.
ChE662A	PETROLEUM REFINERY ENGINEERING	3-0-0-0-9	Petroleum refining in India; refinery tests and crude oil evaluation; crude distillation column design; Delayed Coking; Catalytic cracking; Catalytic reforming; Catalytic isomerization; Alkylation; Polymerization; Hydrocracking; Hydrotreating.
ChE664	ELECTROCHEMICAL ENERGY CONVERSION AND STORAGE	3-0-0-0-4	I.Introduction to electrochemical energy conversion and storage devices (2weeks); a. Contemporary energy challenges and opportunities; b. Advantages and disadvantages in electrochemical approach to energy conversion and storagec. Qualitative introduction to fuel cells; Photoelectrochemical cells, batteries, supercapacitors and thermoelectric devices; 2. Thermodynamics of electrochemical systems (2 weeks) a. Electrochemical potential b. Activity coefficientsc. Reference electrodesd. Junction potential; 3. Electrodics (3 weeks) a. Electrochemical double layer b. Electrode kineticsb. Electrode kinetics; 4. Transport processes in electrochemical systems (3 weeks) a. Transport in diiure soiutionsb. Transport in concentrated solutions. Transport phenomena in electrochemically reactive systems5. Electrochemical measurements (I week) a. Cyclic voltametry b. Impedance spectroscopy. Scanning probe techniques 6. Design issues in electrochemical energy devices (3 weeks) a. Current distribution in Fuel cells and Batteriesb. Material design strategies for

			electrodes/electrolytes c. Economics of Electrochemical devices. **Course Reference**: 1. Newman, J. and Thomas Aiyea, K., Electrochemical systems, WileyInterscience (2004); 2. Larminie, J. and Dicks, A., Fuel cells systems explained, JohnWiley & Sons (2003); 3. Linden, D. ed., Handbook of Batteries, McGrawHill (2001); 4. Bard, A. and Faulkner, L.R, Electrochemical methods, JohnWiley & Sons(2001); 5. Bockris, J.O.M. and Reddy, A.K.N., Modern Electrochemistry (Volume 1, Volume 2A and 2B),Springer (2001); 6. Course materials will be supplemented with research and reviews for journals.
ChE670	INTRODUCTION TO POLYMER SCIENCE AND TECHNOLOGY	3-0-0--4	Polymer Fundamentals: Chemistry of Polymer synthesis, Polymer Reaction Kinetics: Stepgrowth polymerization, free radical chain growth polymerization, Emulsion Polymerization, Ionic and cationic polymerization. Chain statistics and rubber elasticity. Physical properties and characterization of polymers.
ChE670A	INTRODUCTION TO POLIMER SCIENCE & TECHNOLOGY	3-0-0-0-9	Polymer Fundamentals: Chemistry of Polymer synthesis, Polymer Reaction Kinetics: Stepgrowth polymerization, freeradical chain growth polymerization, Emulsion Polymerization, Ionic and cationic polymerization. Chain statistics and rubber elasticity. Physical properties and characterization of polymers.
ChE672	PRINCIPLES OF POLYMER PROCESSING	3-0-0--4	Review of equations of motion, constitutive equations; Calendaring, extrusion; molding; mixing; fibre spinning.
ChE672A	PRINCIPLES OF POLYMER PROCESSING	3-0-0-0-9	Review of equations of motion, constitutive equations; Calendaring, extrusion; molding; mixing; fibre spinning.
ChE673A	ENVIROMENTAL POLLUTION CONTROL, DESIGN AND MODELLING	3-0-0-0-9	1. Air Pollution: a. Introduction: Atmospheric pollutants: definition, sources, concentration levels, units. b. Gaseous phase chemistry: photochemical smog in troposphere; O3 depletion in stratosphere; NOx formation in urban atmosphere, PAN/PAH formation. c. Aqueous phase chemistry: acid rain (SO2, CO2, NO2), Chemical equilibria.d. Aerosols: size, distribution, deposition, visibility degradation, nucleation. f. Mass transfer aspects: diffusion, mass transfer coefficient, characteristics times. g. Troposphere energy balance: pressure temperature relationship, stability criteria, rising parcel of air pollutants, stack plume rise. h. Atmospheric dispersion: puff and plume dispersion, Gaussian models. i. Control of Pollutants: (1) Absorption: design of an absorber (SO2, CO2, NO2) (2) Adsorption: design of an adsorber (SO2, VOC), breakthrough analysis (3) Particles: mechanism of particles capture, fabric filters, cyclones, precipitator2. Water Pollutiona. Introduction: organic/inorganic/biological pollutants, water quality and parameters. b. Waste water treatment: primary and secondary treatments, sludge disposal (aerobic and anaerobic digesters. c. Biological organic wastes: BOD/COD, dissolved O2 model, Monods kinetics,

			biomass growth & food utilization. d. Biological wastewater treatment equipment design: (1) Activated sludge process reactor (2) Trickling filter (3) Biotower reactor. e. Advanced waste water reactors: (1) Continuous counter current multi stage fluidized bed. (2) Moving bed adsorption systems. **Course Reference**: 1. Atmospheric Chemistry and Physics by Seinfeld and Pandis (Wiley.); 2. Environmental Engineering by Peavy, Rowe, and Tchobanoglous (McGraw Hill.)
ChE674	INTRODUCTION TO NANOSCIENCE AND TECHNOLOGY	3-0-0-0-4	1. Overview nanoscience: Important concepts such as size, quantum effect, andMoores law. Characteristic length scales determining the behavior of physical andbiological systems; fundamental phenomena as a function of size and reduceddimensionality; different types of nanomaterials (metal, magnetic, quantum dots,lanthanidebased nanoparticles, polymer nanoparticles, carbon nanotubes and theirproperties (11 lectures); 2. Synthesis and organization of nanomaterials: Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and coprecipitation; Metal nanocrystals by reduction, Solgel synthesis; Microemulsions or reverse micelles, Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis; Sonochemical synthesis; selfassembly; lithography; microfluidics; and chemical vapor deposition; surface modification of nanoparticles (8 lectures); 3. Characterization techniques: Beam probe methods (TEM, EDX, SEM, EDX, andXray scattering), Scanning probe methods (STM and AFM) and other techniques(Optical Spectroscopy, Chromatography, Surface Plasmon Resonance and LightScattering) (1 0 lectures); 4. Application of nanoscience and technology: Drug delivery, Tissue engineering,biosensors, catalysis, and electronics (5 lectures); 5. Discussion on research papers based on the above syllabus. This will be done inbetween the above topics (8 lectures). **Course Reference**: 1. Christof M. Niemeyer, Chad A. Mirkin, Nanobiotechnology: Concepts, applications and perpectives, Wiley Interscience (2004); 2. Geoffery A. Ozin, Andre C. Arsenault, Nanochemistry: A chemical approach tonanomaterials, RSC publishing (2005); 3. M. Gross, Travels to the nanoworld, Plenum Publishing Corporation (2001)
ChE674A	INTRODUCTION TO NANOSCIENCE AND TECHNOLOGY	3-0-0-0-9	1. Overview nanoscience: Important concepts such as size, quantum effect, and Moores law. Characteristic length scales determining the behavior of physical and biological systems; fundamental phenomena as a function of size and reduced dimensionality; different types of nanomaterials (metal, magnetic, quantum dots,lanthanide based nanoparticles, polymer nanoparticles, carbon nanotubes and theirproperties (11 lectures); 2. Synthesis and organization of nanomaterials: Chemical Routes for Synthesis

			ofNanomaterials: Chemical precipitation and coprecipitation; Metal nanocrystals byreduction, Solgel synthesis; Microemulsions or reverse micelles, Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis; Sonochemical synthesis; selfassembly ;lithography; microfluidics; and chemical vapor deposition; surface modification of nanoparticles (8 lectures); 3. Characterization techniques: Beam probe methods (TEM, EDX, SEM, EDX, and Xray scattering), Scanning probe methods (STM and AFM) and other techniques(Optical Spectroscopy, Chromatography, Surface Plasmon Resonance and LightScattering) (1 0 lectures); 4. Application of nanoscience and technology: Drug delivery, Tissue engineering, biosensors, catalysis, and electronics (5 lectures); 5. Discussion on research papers based on the above syllabus. This will be done inbetween the above topics (8 lectures). **Course Reference**: 1. Christof M. Niemeyer, Chad A. Mirkin, Nanobiotechnology: Concepts, applications and perpectives, Wiley Interscience (2004); 2. Geoffery A. Ozin, Andre C. Arsenault, Nanochemistry: A chemical approach to nanomaterials, RSC publishing (2005); 3. M. Gross, Travels to the nanoworld, Plenum Publishing Corporation (2001)
ChE676	ENGINEERING APPLICATIONS OF RHEOLOGY	3-0-0--4	Classification of fluid behaviour: Constitutive relations; Rheometry: Flow of nonNewtonian fluids in closed conduits: Flow in complex geometries: Fixed and fluidized beds; two phase flows, Mixing and agitation: requirements; Dimensional analysis; heat and mass transfer processes in nonNewtonian systems.
ChE676A	ENGINEERING APPLICATIONS OF RHEOLOGY	3-0-0-0-9	Classification of fluid behaviour: Constitutive relations; Rheometry: Flow of nonNewtonian fluids in closed conduits: Flow in complex geometries: Fixed andfluidized beds; two phase flows, Mixing and agitation: requirements; Dimensional analysis; heat and mass transfer processes in nonNewtonian systems.
ChE678	MECHANICS OF SOFT MATERIALS	3-0-0--4	1. Fundamental Equations: The strain tensor; The stress tensor; Thermodynamics of deformation; Hooke's law; Homogeneous deformations; Equilibrium of an elasticmedium bounded by a plane; Solid bodies in contact with and without interactions. (10 hours); 2. Equilibrium of rods and plates: Equations of equilibrium of rods; Bending and torsion of rods. Equation of equilibrium for a bent plate; The energy of a bent plate; Application of bending plate geometry for solving problems related to Adhesion. (10 hours); 3. Nonlinear elasticity: Molecular approach to rubber; strain energy theory; specific forms of strain energy; NeoHookean elasticity. Solutions for incompressible materials. Cavitation in crosslinked networks. (10 hours); 4. Mechanics of cell wall: Elasticity of cellular filaments; soft networks in cell; biomembranes, membrane undulations. (10 hours). **Course Reference**: 1. Theory of Elasticity, 3rd edition by

			Landau and Lifshitz. Course of theoretical physics, vol7; 2. A treatise on the mathematical theory of elasticity by A. E. H. Love; 3. Contact Mechanics by K. L. Johnson; 4. Mechanics of the cell by David Boal.
ChE678A	MECHANICS OF SOFT MATERIALS	3-0-0-0-9	1. Fundamental Equations: The strain tensor; The stress tensor; Thermodynamics of deformation; Hooke's law; Homogeneous deformations; Equilibrium of an elastic medium bounded by a plane; Solid bodies in contact with and without interactions. (10 hours); 2. Equilibrium of rods and plates: Equations of equilibrium of rods; Bending and torsion of rods. Equation of equilibrium for a bent plate; The energy of a bent plate; Application of bending plate geometry for solving problems related to Adhesion. (10 hours); 3. Nonlinear elasticity: Molecular approach to rubber; strain energy theory; specific forms of strain energy; NeoHookean elasticity. Solutions for incompressible materials. Cavitation in crosslinked networks. (10 hours); 4. Mechanics of cell wall: Elasticity of cellular filaments; soft networks in cell; biomembranes, membrane undulations. (10 hours) **Course Reference**: 1. Theory of Elasticity, 3rd edition by Landau and Lifshitz. Course of theoretical physics, vol7; 2. A treatise on the mathematical theory of elasticity by A. E. H. Love; 3. Contact Mechanics by K. L. Johnson; 4. Mechanics of the cell by David Boal.
ChE679	SPECIAL TOPICS	3-0-0--4	Course contents vary from time to time
ChE679A	SPECIAL TOPICS	3-0-0-0-9	Part 1: Introduction to granular materials, Issues and challenges in experimental studies; Discrete element method for granular simulations; Hard and soft particle models; Contact force modelling, Algorithm for softand hard particle methods; Calculation of various properties of interestfrom the data; Some fundamental insights obtained from DEM. Part 2: Continuum models (Balance laws for mass, momentum and energy);Static properties of granular piles (Role of friction, Reynolds dilatancy,Pressure distribution in cylindrical container); Theory of slow flows; Flow through hoppers and wedge shaped bunkers; Rapid flow of smooth, inelastic grains in simple geometries, Hydrodynamic description of rapid granular flows, Heuristic theory and introduction to Kinetic theory of inelastic gases .Part 3: Dense granular flow rheology, inertial number rheology in dense flow regime, 3D viscoplastic rheological model, extension to the rheology of granular mixtures; Surface flows of granular materials, Flow overinclined plane and in rotating cylinders and heaps, depth average equations for surface flows; Mixing and segregation of granular mixtures, Savages kinetic sieving model, Khakhars single particle based segregation model,kinetic theory based segregation models.
ChE681	ADVANCED PROCESS DYNAMICS &	3-0-0--4	Process Identification Techniques for SISO & MIMO systems off line & on line; Generalized Predictive Control (GPC); Model Predictive Control (MPC): DynamicMatrix

	CONTROL		Control (DMC), Internal Model Control for SISO & MIMO systems; OptimalControl; Multivariable Control; Control Design for Complete Plants; Case Studiesusing MATLAB & SIMULINK software.
ChE681A	ADVANCED PROCESS DYNAMICS & CONTROL	3-0-0-0-9	Process Identification Techniques for SISO & MIMO systems off line & on line; Generalized Predictive Control (GPC); Model Predictive Control (MPC): DynamicMatrix Control (DMC), Internal Model Control for SISO & MIMO systems; OptimalControl; Multivariable Control; Control Design for Complete Plants; Case Studiesusing MATLAB & SIMULINK software.
ChE684	AN INTRODUCTION TO SYSTEMS BIOLOGY	3-0-0-0-4	Introduction to transcription Networks; The Concept of Network Motif; Autoregulation loops: Positive and Negative autoregulation; FeedForward loops; Global structure of Transcription Networks and Temporal responses; Network motifs in Development, Signal Transduction, and Neuronal Networks; Robustness of Protein Circuits; Kinetic Proofreading; Optimal gene circuit design; Demand rule for gene regulation; Input function of a Gene: Michaelis Menten and Hill equations, Multidimensional input functions .Duration: One Semester **Course Reference**:1. An Introduction to Systems Biology by Uri A ton. (Chapman & 1Iaii/CRC, UK, 2007); 2. Mathematical Models in Biology by EdelsteinKeshet, L. (Cambridge University Press,2005); 3. Systems Biology Properties of restructured Networks by Bernhard 0. Palsson (Cambridge University Press, 2006); 4. Virus dynamics: Mathematical principles of immunology and virology by Martin A. Nowak And Robert may (Oxford University press, USA,2001)
ChE684A	AN INTRODUCTION TO SYSTEMS BIOLOGY	3-0-0-0-9	Introduction to transcription Networks; The Concept of Network Motif; Autoregulation loops: Positive and Negative autoregulation; Feed Forward loops; Global structure of Transcription Networks and Temporal responses; Network motifs in Development, Signal Transduction, and Neuronal Networks; Robustness of Protein Circuits; Kinetic Proof reading; Optimal gene circuit design; Demand rule for gene regulation; Input function of a Gene: Michaelis Menten and Hill equations, Multidimensional input functions .Duration: One Semester **Course Reference**:1. An Introduction to Systems Biology by Uri A ton. (Chapman & 1Iaii/CRC, UK, 2007); 2. Mathematical Models in Biology by Edelstein Keshet, L. (Cambridge University Press,2005); 3. Systems Biology Properties of restructured Networks by Bernhard 0. Palsson (Cambridge University Press, 2006); 4. Virus dynamics: Mathematical principles of immunology and virology by Martin A. Nowak And Robert may (Oxford University press, USA,2001)
ChE687A	QUANTUM MECHANICAL		Quantum phenomena and its scope in engineering, Quantum Mechanics of Simple Systems, Models for

	DESIGN OF ENGINEERING MATERIALS & INDUSTRIAL CATALYSTS		Properties of Matter from Electronic and Atomic Structure, Ab-Intio Thermodynamics, quantum mechanics and Battery Engineering, Quantum Mechanical Design of Fuel Cells and Solar Cells, Sabatier Principle and Industrial Catalysts Design.
ChE688	FUNDM. OF COLLOID & INTERFACE SCI. & TECH.	3-0-0--4	Capillarity, interfacial thermodynamics, surflactants, stability of multiphasesystems, foam, emulsion, multiphase reactors, wetting and adhesion, catalystsintering/redispersion; Stability and coagulation of colloids, nucleation andgrowth: Colloids in chemical engineering, in separation processes, bioscience.
ChE688A	FUNDM. OF COLLOID & INTERFACE SCI. & TECH.	3-0-0-0-9	Capillarity, interfacial thermodynamics, surflactants, stability of multiphase systems, foam, emulsion, multiphase reactors, wetting and adhesion, catalystsintering/redispersion; Stability and coagulation of colloids, nucleation andgrowth: Colloids in chemical engineering, in separation processes, bioscience.
ChE699	M TECH THESIS	----	M. Tech. Thesis
ChE699.	M TECH THESIS (FOR DUAL DEGREE ONLY)	0-0-0--9	M TECH THESIS (FOR DUAL DEGREE ONLY)
ChE701	M. TECH. SEMINAR	----0	M. Tech. Seminar
ChE701A	M. TECH. SEMINAR	0-0-0-0-0	M. Tech. Seminar
ChE702	M TECH SEMINAR	0-0-0--0	M. Tech. Seminar
ChE799	PHD THESIS	0-0-0--0	Ph. D. Thesis
ChE801	PHD SEMINAR	----0	Ph. D. Seminar
ChE802	PHD SEMINAR	----0	Ph. D. Seminar
ESO201A	THERMODYNAMICS	3-1-0-0-11	Definitions & concepts: SI Units; System; Property; Energy; Thermodynamic Equilibrium; Work, State Postulate; Zeroth Law of Thermodynamics; Temperature Scale, Thermodynamic Properties of Fluids: Mathematical, Tabular and Graphical representation of data; Ideal gas Van der Waals Equation of state; Compressibility chart; Thermodynamic Diagrams including Mollier diagram; Steam Tables, First law of Thermodynamics & its applications to Non flow processes, Applications of First Law of Thermodynamics of Flow Processes; Steady state Steady flowand Transient flow processes, Applications of First Law of Thermodynamics to Chemically Reacting Systems Second Law of Thermodynamics & its Applications, Thermodynamic Potentials, Maxwells Relations; Thermodynamic Relations and Availability, Power Cycles, Refrigeration Cycles; SI Units, Definitions & Concepts: System, Property, Energy, Thermodynamic Equilibrium, Work interaction &various modes of work, Heat, State Postulate, Zeroeth Law of Thermodynamics,Temperature Scale, IPTS. Thermodynamic Properties of Fluids: Pure substance. Phase, Simple compressible substance, Ideal gas

			Equation of state, van der Waals Equation of State; Lawof corresponding states, Compressibility chart, Pressurevolume; Temperature volume and Phase diagrams; Mollier diagram and Steam tables.
ESO212	FLUID MECHANICS AND RATE PROCESSES	3-1-0-1-4	I. FLUID MECHANICS (34 lectures) 1. Introduction to transport phenomena; 2. Fluid statics; pressure as a scalar, manometry, forces on submerged surfaces by integration of pressure forces; 3. Description of flows; Lagrangian and Eulerian approaches; Euler acceleration formula; streamlines; control volume; 4. Conservation of mass; integral and differential approaches; 5. Linear momentum balance: stress; deformation; Newtons law of viscosity; NavierStokes equation; 6. Applications of NavierStokes equation for simple 1D problems; Poiseuille flow, Couette flow; 7. Total energy equation; Bernoulli equation; applications including flow measurement (Pitot tube, orifice meters); 8. Pipe flows; friction factor; Reynolds experiment; losses in fittings; 9. Similitude and modeling using nondimensionalization of Navier Stokes equations and boundary conditions, simplifications for cases without free surfaces and without cavitation (scale factor approach should NOT be done); 10. Low Re flows: flow past circular cylinders; stream functions; Stokes flow; drag coefficient correlations; 11. High Re flow: Prandtls approximation; basic inviscid flow; need for boundary layer; MagnusRobin effect; 12. Boundary layer flow; flow on flat plates; separation; flow past immersed bodies (bluff, streamlined); physics of ballgames(qualitative)II. HEAT TRANSFER1. Introduction: Fouriers law; unsteady conduction equation; boundary conditions; 2. Convection: heat transfer coefficient and correlations III. MASS TRANSFER. Introduction; Ficks law; unsteady species conservation equations mass transfer coefficent and correlations. **Course Reference**: 1.V. Gupta and S.K. Gupta, Fluid Mechanics and its Applications, New Age Intl., NewDelhi, 1984; 2. V. Gupta, Elements of Heat and Mass Transfer, New Age Intl., New Delhi, 1995; 3. R. W. Fox, P. J. Pritchard and A. T. McDonald, Introduction to Fluid Mechanics, 7th Ed.,Wiley, 2008; 4. J. Lighthill, Physiological Fluid Mechanics, Springer, 1972; 5. J. P.Holman, Heat Transfer, 10th Ed., McGraw Hill, 2009.

CIVIL ENGINEERING

CIVIL ENGINEERING

B.TECH. — Template No. CE-1

	SEMESTER 1st	2nd	3rd	4th	5th	6th	7th	8th
C	MTH101A [11]	MTH102A [11]	CE241 [09]	CE242 [11]	CE311 [12]	CE352A [07]	CE441b [05]	DE-B [09]
O	PHY103A [11]	PHY102A [11]	ESO-1 [11] (ESO202A)	CE262A [08]	CE331A [11]	CE372A [06]	DE-A [11]	OE-4 [09]
U	CHM101A [03]	PHY101A [03]	ESO-2 [11] (ESO204A)	CE272 [09]	CE351A [08]	CE382 [09]	DE-B [09]	HSS-5 (Level-2) [09]
R	LIF101A [06]	ESC101A [14]	HSS-2 (Level-1) [11]		CE361A [06]	HSS-3 (Level-2) [09]	HSS-4 (Level-2) [09]	OE-5 [09]
S	ENG112A/HSS-1 (Level-1) [11]	CHM102A [08]	SO-1 [06] (MSO203B)	ESC201A [14]	CE371A [06]	OE-1 [09]	OE-2 [09]	OE-6 [09]
E	PE101A [03]	PE102A [03]	TA202A [06]	SO-2 [11] (MSO201A)	ESO-3 [11] (ESO208A)	DE-A [11]	OE-3 [09]	UGP-4 [09] (CE493A) (extra credit)
S	TA101A [09]	-	COM200 [05]	TA201A [06]	CE341A [02]	UGP-1 [04] (CE332A) (Extra Credits)	-	-
	54	50	59	59	56	51 – 55	52	45 – 54

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	109	Credits
*Department Elective (DE)	:	40	Credits
Open Elective (OE)	:	54	Credits
SO/ ESO	:	50	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	**426**	**Credits**

BASKET – A	BASKET – B**
CE412 [11]	
CE451 [11]	
CE462 [11]	
CE471 [11]	CE491 [09]
CE481 [11]	CE492 [09]
CE432A [11]	CE605 [05]
	CE606 [05]

REMARKS:

1) *Students need to ensure that the four courses chosen as DE include a minimum of 22 credits from Basket-A, and total to a minimum of 40 credits. Students opting for the dual degree programme within CE have to do a minimum of 31 credits of DE, which should include minimum 22 credits from Basket A.
2) **The DE-B basket may also contain departmental PG courses that may be offered as DE-B from time to time. Students opting for the dual degree programme within CE are allowed to take CE491 or CE492 as DEs from Basket B or as OE.
3) UGP-1 and UGP-4 do not count towards DE/OE credits or minimum graduation requirements.
4) Upto 45 OE credits and 09 DE credits may be waived from the minimum requirements for students opting for the dual degree programme within CE.
5) Upto 36 OE credits may be waived from the minimum requirements for students opting for dual degree in another department or the Double Major programme

"Eligible and interested students can take CE332A as UGP-I, CE49IA as UGP-2, CE492A as UGP-3 and CE493A as UGP-4.
B.Tech students can take CE49IA and CE492A as DE-B only. Dual degree students can take CE49IA and CE492A as either DE-B or OE.
CE332A (UGP-I) and CE493A (UGP-4) are for extra credits and do not count for DE or OE credits required for graduation"

BT-MT (PG Part – Category – A) *(from the same department)* — Template No. CE-2

Sl. No.	Specialization	Compulsory Course Credits	Elective Credits	Thesis Credits
1.	ENVIRONMENTAL ENGINEERING	None	63 Credits	M.Tech. Thesis [72]
2.	GEOINFORMATICS	None	63 Credits	M.Tech. Thesis [72]
3.	GEOTECHNICAL ENGINEERING	None	63 Credits	M.Tech. Thesis [72]
4.	HYDRAULICS AND WATER RESOURCES	None	63 Credits	M.Tech. Thesis [72]
5.	STRUCTURAL ENGINEERING	None	63 Credits	M.Tech. Thesis [72]
6.	TRANSPORTATION ENGINEERING	None	63 Credits	M.Tech. Thesis [72]
7.	INTERDISCIPLINARY	To be decided by advisor(s).	-63 Credits	M.Tech. Thesis [72]

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Coursework	:	63	Credits
Thesis Component	:	72	Credits

REMARKS:

1) Upto one PG course may be replaced with a UG course on advice of the thesis supervisor.
2) Upto 45 OE credits and 09 DE credits may be used from the BT minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the BT programme and counted towards PG requirements. All other BT requirements have to be fulfilled as per the CE BT template.
3) Students opting for the dual degree programme within CE are allowed to take CE491 and/or CE492 as DE from Basket B or as OE.
4) There are no compulsory courses.

BT-MT (Category – B) *(from other departments)*						Template No. **CE-3**
Sl. No.	**Specialization**	**Eligible BT/BS Background**	**Compulsory Courses**		**Elective Credits**	**Thesis Credits**
			UG Pre-Requisites	**PG Courses**		
1.	**ENVIRONMENTAL ENGINEERING**	**BSBE, CHE, CHM, ECO, ME, MME, MTH, PHY**	-	**CE664A CE665A CE666A CE667A CE668A**	**Compulsory + Elective Credits = 63**	**M.Tech. Thesis [72]**
2.	**GEOINFORMATICS**	**CSE, MTH, PHY**	**CE331A**	**CE671A CE677A**	**Compulsory + Elective Credits = 63**	**M.Tech. Thesis [72]**
3.	**HYDRAULICS AND WATER RESOURCES**	**AE, CHE, ME**	-	**CE610A CE611A CE612A CE613A**	**Compulsory + Elective Credits = 63**	**M.Tech. Thesis [72]**
4.	**TRANSPORTATION ENGINEERING**	**AE, ECO*, ME, MTH*, PHY***	**ESO202A* *ECO, MTH, PHY students**	**CE682A OR CE481A CE683A CE689A OR CE688A CE690A**	**Compulsory + Elective Credits = 63**	**M.Tech. Thesis [72]**
5.	**INTERDISCIPLINARY**	-	**To be decided by advisor(s).**			**M.Tech. Thesis [72]**

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Component : 63 Credits (common for all specializations)

Thesis Component : 72 Credits (common for all specializations)

Remarks:

1) Up to 2 UG courses may be taken for PG credit (including the optional PG 8) on advice of the thesis supervisor.
2) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the parent department's BT programme requirements and counted towards PG requirements.

	DOUBLE MAJOR	Template No. **CE-4**
C	**Odd Semester**	**Even Semester**
	Pre-Requisites	
O	**ESO204A/ ME231 [11]**	
	ESO202A [11]	
U	**22**	
	MANDATORY CE COURSES	
R	**CE311A [12]**	**CE242A [11]**
	CE241A [09]	**CE262A [08]**
S	**CE331A [11]**	**CE272A [09]**
E	**CE351A [08]**	**CE352A [07]**
	CE361A [06]	**CE372A [06]**
S	**CE371A [06]**	**CE382A [09]**
	CE DE-A [11]	**CE DE-A [11]**
	63	**61**

MIMINUM CREDIT REQUIREMENT FOR SECOND MAJOR IN CIVIL ENGINEERING: 124 CREDITS

REMARKS:

1) Both DE should be selected from Basket A (Details of Basket A are available in CE B.Tech. template)
2) Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.

MINOR*	Template No. **CE-5**
Title	**Infrastructure Engineering and Management**
C	**CE241 [09] [odd semester]**
O	**CE640 [06] [odd semester]**
U	**CE641a [05] [odd semester]**
R	**CE643a [05] or CE644a [05] [even semester]**
S E	**CE667a [05] [even semester]**
S	-

DEPARTMENT OF CE			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
CE213A	INTRODUCTION TO ENVIRONMENTAL SCIENCE	3-0-0-0-9	Introduction: Define environmental science as a subject that draws on learning's from natural sciences to investigate human impact on the natural environment. Present concept of hydrosphere, atmosphere, biosphere, and ecosystem. Explain how the scientific method is used to investigate natural phenomena, particularly the inter relationships between organisms and among organisms and their environments. Water: Hydrologic Cycle and Water Bodies, Water Availability and Use, Water Pollution, Water Management. Environmental legislation and Policy Development: Examine the need and rationale for environmental legislation and the basis on which they are formulated. Air Pollution and Contrlo; : Classify sources and types of airpollution. Pollution monitoring setup including standards for regulated pollutants. Effect of pollution on human health. Noise Pollution and Control. Climate, Weather, and Air Pollution: Explain the components of the atmosphere and the processes that form climate and climate change. **Course Reference**: 1. Nazaroff, Jerald L. Environmental Engineering and Science, 2004, John Wiley & Sons, Inc.; 2. Environmental Science Towards a Sustainable Future by R.T. Wright and D.F. Boorse; 3. PHI Learning. Environmental Science: Working with the Earth by Miller, G. Tyler, 11th Edition; 4. Enger, Eldon D. and radley F. Smith. Environmental Science: A Study of Interrelationships, 12th edition, McGrawHill, 2009. 11-MAR-2016
CE241A	SUSTAINABLE BUILT ENVIRONMENT	3-0-0-0-9	Module 1: Description of Earth and environment. Earth and Environment Definition of environment; origin of earth, lithosphere, hydrosphere, atmosphere, biosphere. Earth structure, Plate Tectonics theory, Geomorphological features, Geological structures (folds, faults, discontinuity, dike); Engineering and Genetic classifiation of soils, Weathering and Soils; Rocks, rock ecycle, Igneous Rocks, Sedimentary Rocks, Metamorphic Rocks, Rock Properties, Rockwater interaction. Natural disasters: Cyclone, Tornado, Volcanic Eruption, Earthquakes Generation mechanism, different terminologies, earthquake monitoring and measurements, seismic region of the world, Tsunami, Land Slides; Sustainability and resilience for natural disasters. Hydrosphere; water cycle, surface and groundwater origin and its quality, occeans, ocean currents, ocean water quality. **Course Reference**: 1. Loftness, V.; Haase, D. (Eds.) Sustainable Built Environments, Springer, 2013; 2. Yao, R. (Ed). Design and Management of Sustainable Built

			Environments, Springer, 2013; 3. Zetter, R.; Watson, G.B. (Eds.) Designing Sustainable Cities in the Developing World, Ashgate Publishing Ltd., 2006; 4. Graham, P. Building Ecology, WileyBlackwell, 2002. 11-MAR-2016.
CE242A	CIVIL ENGINEERING MATERIALS	3-0-2-0-11	Earth System: Lithosphere, Hydrosphere, Cryosphere and atmosphere and theiriinteractionsSolid Earth: Shape, size, interior of the solid earth. Geological materials: rocks, soils, minerals (clay mineralogy), Engineering and Genetic classification of soils, rocks, rock cycle, rockwater interaction. Earth Processes and their consequences, Geomorphological features, structures (folds, faults) Earthquakes: Causes, classification, magnitude, intensity, Historical earthquakes, Seismic hazards zoning, strong ground motion, earthquake predictionLandslides and Subsidence: Causes, classification and monitoring; Groundwater: Groundwater resources and quality of ground water Geology of India: Physiographic and fectonic divisions; Minral resources. Geophysical mapping: seismic, resistivity, radar, geotomography, logging Remote sensing, GIS and GPS: Basic principles and their applications in monitoring Lithosphere, Hydrosphere, Cryosphere and Atmosphere; Criteria forsite selections for Dam, tunnels, waste/radioactive disposal sites
CE262A	ENGINEERING HYDRAULICS	2-0-2-0-8	Introduction. Review of the basic equations: continuity, momentum, and energy. Flow through closed conduits: Laminar flow, Turbulent flow, Pipes in Series and Parallel, Pipe Networks, Unsteady flow. Flow through openchannels: Uniform flow, Critical flow, Gradually Varied flow, Rapidly Varied flow, Spatially Varied flow, Unsteady flow. Flow Measurement: Pressure, Velocity and Discharge measurements. Forces on immersed bodies: Drag and Lift. Basics of Irrigation Engineering: Crop water requirements, Irrigation methods.
CE272A	STRUCTURAL ANALYSIS	3-0-0-0-9	Stability and Determinacy of Structures. Review of shear force and bending moment diagrams in beams and frames. Plane trusses: method of joints and method of sections. Deflection of trusses: method of virtual work. Deflection of beams and frames: momentarea method, conjugate beam method, method of virtual work. Influence line diagrams and moving loads. Force and stiffness methods of analysis. Plane trusses by using method of consistent deformations. Beams and frames: method of consistent deformations, slopedeflection equation, moment distribution method. Plane trusses and beams by using direct stiffness method. **Course Reference**: 1. Norris, C.H., Wilbur, J.B., and Utku, S., Elementary Structural Analysis, McGraw Hill, Hibbeler, R. C. (2002); 2. Structural Analysis, 6/e, Pearson Hsieh, Y., Elementary Theory of Structures, PrenticeHall; 3.Sack, R.L. (1989) Matrix Structural Analysis, Waveland Press, Inc.Wang, C.K., Intermediate

			Structural Analysis, McGrawHill; 4. Wang, C.K., Statically Indeterminate Structures, McGrawHill.West, H.H., Analysis of Structures, John Wiley.
CE331A	GEOINFORMATICS	3-0-2-0-11	Preview of Geotechnical Problems in Civil Engineering and Infrastructure Development, Description of soil, Engineering geology of soils and their formation, earthquakes and their effects, Stresses within a soil, effective stress principle, stress point and stress path, Soil water systems capillarity, flow,Darcys law, permeability, and tests for its determination, different heads,piping, quicksand condition, seepage, flownets, flow through dams, filters, Compressibility and consolidation characteristics, maximum past stress, OCR,determination of coefficients of consolidation and secondary compression(creep), consolidation under construction loading, Strength and direct and triaxial shear tests, Mohr Coulomb strength criterion, drained, consolidated undrained and undrained tests, strength of loose and dense sands, NC and OC soils, dilation, pore pressures, Skemptons coefficients, etc. Compaction characteristics, water content dry unit weight relationships, OMC, max. dry unit weight, field compaction control, etc. Introduction to Geosynthetics, classification, functions, properties physical, mechanical, hydraulic, environmental, etc. Stability of slopes, limit equilibrium methods, ordinary methods of slices and simplified Bishop method, factors of safety.
CE332A	UNDER GRADUATE RESEARCH -I	0-0-0-0-4	Introduction, examples of foundation problems case studies, Characterisation of ground, site investigations, methods of drilling, sampling, in situ test SPT, CPT, plate load and dynamic tests, ground water level, etc. Bearing capacity, general, local and punching shear failures, corrections for size, shape, depth,water table, compressibility, etc., ultimate and allowable stresses, methods based on in situ tests, Settlements of foundations, stress in soils (Boussinesq,Westergaard, Mindlin solutions), one and two dimensional cases, immediate, consolidation and creep settlements, methods based on in situ tests, Limit State Design, stability and serviceability states, load and strength factors, Types of foundations shallow/deep, isolated, combined, mat, etc., contact pressure distributions, soil foundation interactions, basics of structural design, Ground Improvement Techniques, methods for difficult or problematic ground conditions softsoils, loose sands, seismic conditions, expansive or collapsible soils, etc.,preloading, vertical drains, stone columns, heavy tamping, grouting, etc. Earth Pressure Theories, Coulomb and Rankine ap proaches, cf soils, smooth and rough walls, inclined backfill, depth of tension crack, Retaining structures, gravity, cantilever, counterfort, reinforced earth, etc., design and checks for stability, Deep foundations, piles, pile groups, well foundations, underreamed piles, precast,driven cast in situ and bored

			piles, shaft and base resistances, downdrag, pile load tests, Selected Topics machine foundations/introduction to environmental geotechnique/application of geosynthetics, etc
CE341A	CIVIL ENGINEERING COMMUNICATION SKILLS	0-0-2-0-2	civil engineering communication skills
CE351A	SOIL MECHANICS	2-0-2-0-8	Stresses within a soil, effective stress principle, stress point and stress path, Soil water systems capillarity, flow Darcys law, permeability, and tests for its determination, different heads, piping, quicksand condition, seepage, flow nets Compressibility and consolidation characteristics, Strength of loose and dense sands, NC and OC soils, dilation, pore pressures, Skemptons coefficients, etc. Compaction characteristics, water content dry unit weight relationships, OMC, max. dry unit weight, field compaction control, etc. **Course Reference**: 1. Craig RF., Craigs Soil Mechanics., 2004, Taylor and Francis, New York, USA.Das BM; 2. Advanced Soil Mechanics., 2008, Taylor and Francis, New York, USA.LambeTW., and Whitman RV., Soil Mechanics., 2000, John Wiley and Sons (Asia), Singapore.
CE352A	FOUNDATION DESIGN	2-0-1-0-7	Ideal and nonideal VLE (TxyPxy plots, Azeotrope): Computation of 2+2VLE data (Temperaturecomposition, Pressurecomposition plots) using (i)ideal mixture assumption and (ii) using various activity coefficient modelssuch as VanLaar model, UNIFAC etc. Special emphasis on VLE ofazeotropic mixtures. Examples: Benzene ethanol, Furfuralwater, benzenecyclohexane mixtures. Two film model for mass transfer between gas and Iiguid (e.g. C02 absorption using K2C03 solution, NH3 absorption in dilute acid solution): Study of the absorption, reaction and diffusion processes in a contactreactor/bubble absorber/packed tower/plate column through the twofilmmodel. Formulation of the steadystate problem in terms of differentialequations for gas and liquid phase species using Fick's law, the gasliquid equilibrium relations, and reaction rate expressions. Effect of limiting diffusion and reaction steps. Numerical solution methods. **Course Reference**: 1. Introduction to chemical engineering computing by B. A. Finlayson; Indian edition by JohnWiley; 2. Chemical Process Modelling and Computer Simulation by A. K. Jana; PHI learning, 2008; 3. Luyben W.L, Heuristic Design of Reaction/Separation Processes, Ind. Eng. Chern. Res., 49,11564 (2010).
CE361A	ENGINEERING HYDROLOGY	2-0-0-0-6	Introduction: Hydrologic cycle, water budget, world water quantities,precipitation and abstractions: Forms of precipitation, data analysis, raingauge networks; Infiltration process, infiltration indices and Horton's equation; Evaporation and Evapotranspiration Pan evaporation, empirical equations forestimating

			evaporation and evapotranspiration; Transpiration Runoff and Hydrographs: Rainfall runoff relations, time area concept, flow duration curve, mass curve, flow hydrograph, Unit Hydrograph (UH), its analysis, Scurve hydrograph Floods and Routing: Concepts of return period, flood frequency analysis, Gumbel's and LogPearson Type III distributions,Rational method, risk, reliability, and safety factor; Hydrologic storage routing Groundwater Hydrology: Types of aquifers and properties, Darcy's law, steady flow in a confined and unconfined aquifer (without recharge), steady flow to a well. **Course Reference**: I. Engineering Hydrology by K Subramanya, Tata McGraw Hill, New Deih; 2. Applied Hydrology by V. T. Chow, David Maidment, and Larry Mays, TataMcGraw Hill, New Delhi, India.
CE371A	DESIGN OF STEEL STRUCTURES	2-0-0-0-6	Steel structures, Limit states and design philosophy; partial safety factors and load combinations; Analysis and design methods; Design of tension members based on net section including shear lag effects, staggered holes and blockshear; Design of compression members for flexural and flexural torsional buckling,Column formula, Local buckling and buckling class, End restraints and effective length factor; Role of plate buckling, Plastic hinge, Classification of section: plastic,compact, semicompact, slender, Design strength of laterally supported beams, Shearbuckling strength Postcritical method, Shear moment interaction, Design strength of laterally unsupported beams, Lateral torsional buckling, Effect of restraints and effective length; Effect of axial load on flexure behaviour, Crosssection yielding and member instability, PM interaction and moment amplification, Biaxial bending; Design of Bolts and Welds, Strength under combined stresses, Prying action,Common simple and eccentric joints and frame connections, Column bases. **Course Reference**: 1. Subramanian, N. (2008). Design of Steel Structures, OxfordUniversity Press; 2. Bhavikatti, S. S. (20 10). Design of Steel Structures (by LimitState Method as Per IS: 8002007), IK International; 3. Segui, W.T. (2007). Design of Steel Structures, Cengage Learning
CE372A	REINFORCED CEMENT CONCRETE DESIGN	2-0-0-0-6	Reinforced concrete (RC) structures, Loadings, analytical models for analysis and design of RC structures, Design Methodologies: Working Stress Method and Limit State Method; Behaviour of RC members under flexure; Working stress design for common flexural members; Limit state design of beams and slabs (oneway and two way) for flexure; Singly and doubly reinforced sections; rectangular and flanged sections; S hear and torsion; Bond and anchorage; Short columns under axial compression, Short columns under axial compression with uniaxial bending, Short columns under axial compression with biaxial bending. Slender columns

			Types of footings; design of isolated / combined footing. **Course Reference**: 1. Sinha, S.N., Reinforced Concrete Design, Tata McGraw HillPillai, S.U., and Menon, D., Reinforced Concrete Design, Tata McGraw Hill, 2009; 2. Nilson, A.H., and Winter, G., Design of Concrete Structures, McGraw Hill, New DelhiPark, R. and Paulay, T., Reinforced Concrete Structures, John WileyFerguson, P.M., Bren, J.E. and Jirsa, J.O; 3. Reinforced Concrete Fundamentals, John Wiley and Sons, New YorkMcGregor, J.M., Reinforced Concrete Mechanics and Design, Prentice Hall, New York
CE373	SURVEY AND GEOLOGY CAMP	0-0-0--2	Survey Camp: Reconnaissance and establishing the stations; Base line measurements, Triangulation readings on various stations; computation andpreparation of triangulation map; contouring; preparation of map; preparationof report. Geology Camp: Reconnaissance of the area; Elementary geological field mappingof rock formations and structural details; Geomorphic processes Preparation of report.
CE382A	TRANSPORTATION ENGINEERING	3-0-0-0-9	Analysis of Traffic Flow, Design of Traffic facilities, Pavement Analysis, Pavement Design, Highway Construction, Highway Maintenance. Introduction to Transportation engineering elements, Geometric design, Traffic flow fundamentals, Uninterrupted traffic flow, Interrupted traffic flow, Pavement analysis, Highway maintenance **Course Reference**: 1. Chakraborty, P. and Das, A., Principles of Transportation Engineering, Prentice Hall of india, 2003; 2. Garder, N.J. and Hoe! L.A., Traffic & Highway Engineering; 3. Ed.,Brooks/Cole, Pacific Grove, 2001; 4. McShane W.R, Roess R.P., Prassas, E.S.,Traffic Engineering, 2nd Ed.,Prentice Hall 1998
CE412A	WATER SUPPLY AND WASTEWATER DISPOSAL SYSTEMS	3-0-2-0-11	Introduction and Scope; Analysis and Design of Water Treatment Systems; Design of Water Distribution Networks; Analysis and Designof wastewater Collection Systems; Analysis and Design of Waste Water Treatment Systems; Rural Water Supply and Sanitation; Environmental Engineering. **Course Reference**: 1. Authors: H. Peavy, D. Row and G. Tchobanoglous. Publisher: Tata McGrawHill.Water Supply and Pollution Control; 2. Warren Viessman Jr. and Mark J. Hammer. Edition 2005. Publisher: Pearson Education (Indian Edition Available); 3. Wastewater Engineering; Treatment, Disposal, Reuse. Editors: Metcalf & Eddy. 3rd Edition (1995). Publisher: Tala McGrawHill (Indian Edition Available); 4. Additional class notes and reference material will be provided during lectures, either in softcopy or hardcopy form.
CE451A	APPLICATION OF GEOTECHNICAL ENGINEERING	3-0-0-2-11	Earth and Earth retaining structures: Slope stability analysis, flexible and rigid retaining wall, gravity, cantilever, counter fort, reinforced earth etc., design and check for stability. Introduction to ground improvement techniques: methods for difficult or problematic ground

			conditions for soft clays, loose sands, expansive or collapsible soils etc., preloading, vertical drains, stone columns, heavy tamping, grouting etc., Machine foundation and design. **Course Reference**: 1.Das BM., Principles of Geotechnical Engineering, 2007, Thomson, IndiaDas BM., Theoretical Foundation Engineering, 2008, Cengage Learning India Private limited, India; 2. Bowles JE., Foundation Analysis and Design, 1997, McGrawHill Companies, Singapore; 3.Swami Saran., Reinforced soil and its Engineering applications, 2010, I.K. International publishing house private limited, India; 4.Mittal S., An introduction to Ground Improvement Engineering, 2013, Scientific International private limited, India.Research papers from Journals and Conference proceedings.
CE462A	HYDRAULIC AND HYDROLOGIC DESIGN	3-1-0-0-11	Synthetic design storms & Estimation of peak discharge, Urbanstorm drainage design, Culvert design, Detention storage design, Watershed modeling, Flood frequency analysis and hydrologic design under uncertainty; Designof water distribution network, Analysis and design of rigid boundary channels,Tractive force concepts in channel design, Design of canal headworks, distribution works, and cross drainage works, Design of gravity dams, spillways, and energy dissipators. **Course Reference**: 1. Hydrologic Analysis and Design by Richard H. McCuen, Prentice Hall, NewJersey, USA; 2. Applied Hydrology by V. T. Chow, David Maidment, and Larry Mays, TataMcGraw Hill, New Delhi, India; 3. Hydraulic Design Handbook by Larry W. Mays, McGraw Hill.
CE471A	SPECIAL TOPICS IN STRUCTURAL DESIGN	3-0-0-2-11	Elements of Prestressed concrete; Introduction to seismic design; Introduction to design of masonry structures; Case studies in design of RC Structures (RC water tank, Building frame, etc.), Case studies in design of steel structuresIndustrial buildings, towers, chimneys, Plate girder, chimneys) **Course Reference**: 1. Pillai, S.U., and Menon, D., Reinforced Concrete Design, Tata McGraw Hill, 2009; 2. Sinha, S.N., Reinforced Concrete Design, Tata McGraw Hill; 3. Subramanian N. (2008). Design of Steel Structures, Oxford University Press; 4. Bhavikatti, S. S. (201 0). Design of Steel Structures (by Limit State Method as Per IS:8002007), IK International; 5. Krishna Raju N. (1995). Prestressed Concrete, Tata McGraw Hill; 6. Dayaratnam, P., Brick and Reinforced Brick Structures, Oxford & IBH PublishingHouse, 1997
CE481A	TRANSPORTATION FACILITIES DESIGN	3-0-0-2-11	Any two of the three modules listed below will be taught in any semester :Module 1Traffic Design : Introduction, freeway and toll booths, intersections/interchanges, signs and lighting, arterials/ weaving section, congestion mitigation.Module 2Pavement Design : Introduction, design parameters, bituminous pavement, concrete pavement, composite pavement.Module 3Geometric Design: Introduction, design controls and criteria,

			freeway design, arterial/collector design, atgrade intersections, terminals. **Course Reference**: 1.Chakroborty, P. and Das, A., Principles of Transportation Engineering, Prentice Hall of India, 2003; 2.Garder, N.J. and Hoel, L.A., Traffic & Highway Engineering, 3rd Ed., Brooks/Cole, Pacific Grove, 2001; 3.McShane W.R., ROess R.P., Prassas, E.S;Traffic Engineering, 2nd Ed., Prentice Hall 1998; Americal Association of State Highway and Transportation Officals (AASHTO), A Policy on Geometric Design of Highways and Streets, 5th Ed., AASHTO, 2004
CE491	PROJECT - I	0-0-6-2-0	PROJECT I
CE491A	UNDER GRADUATE RESEARCH -II	0-0-0-0-9	UNDER GRADUATE RESEARCH I
CE492A	UNDER GRADUATE RESEARCH -III	0-0-0-0-9	UNDER GRADUATE RESEARCH II
CE601	STATISTICAL ANALYSIS FOR CIVIL ENGINEERS	3-0-0--4	1. Basic Concept of Probability and Distributions; 2. Experimental Error and their Characteristics(a) Random error(b) Bias(c) Propagation of random error(d) Error due to rounding off(e) Calibration; 3. Adjustment Computations(a) Condition method (b) Observation method (c) Combined method; 4. Sampling(a) Population and sample(b) Sample designs(c) Sample statistics(d) Sampling distribution of mean and variance(e) Question of sample size; 5. Estimation and Hypothesis Testing(a) Properties of good estimates(b) Interval estimation(c) Maximum likelihood estimates(d) Sample size determination(e) Basic fonnat of hypothesis testing(f) Type I and Type II errors(g) One and two tailed tests(h) Tests on mean and variance from samples under different assumptions and knowledge of the underlying distribution; 6. Regression Analysis and Hypothesis Testing(a) OLS estimates(b) Assumptions and proof of BLUE(c) Detection, effect, and remedy of multicollinearity(d) Detection, effect, and remedy of heteroskedasticity(e) Detection, effect, and remedy of autocorrelation(f) Misspecification errors and regression model building(g) Hypothesis testing on OLS estimates(h) GIS(i) Comparison of regression modelU) Use of dummy independent variables(k) Robust regression and effect of outliers; 7. Miscellaneous Topics(a) Fitting theoretical distributions to observed frequency distributions (b) Tests of goodnessoffit (chisquare test, KolmogorovSmirnov test) (c) Identification of outliers(d) Cluster analysis; 8. Practical applications with (Civil) engineering data. **Course Reference**: 1. Experimentation and Uncertainty Analysis: Hugh M. Coleman and W.G. Steele; 2. Handbook of statistical Methods for Scientists and Engineers: H.M. Wadsworth; 3. Statistical Treatment of Experimental Data: J.R. Green and D. Margerison4. Basic Econometrics: Damodar Gujarati

CE601A	STATISTICAL ANALYSIS FOR CIVIL ENGINEERS	3-0-0-0-9	1. Basic Concept of Probability and Distributions; 2. Experimental Error and their Characteristics(a) Random error(b) Bias(c) Propagation of random error(d) Error due to rounding off(e) Calibration; 3. Adjustment Computations(a) Condition method (b) Observation method (c) Combined method; 4. Sampling(a) Population and sample(b) Sample designs(c) Sample statistics(d) Sampling distribution of mean and variance(e) Question of sample size; 5. Estimation and Hypothesis Testing(a) Properties of good estimates(b) Interval estimation(c) Maximum likelihood estimates(d) Sample size determination(e) Basic fonnat of hypothesis testing(f) Type I and Type II errors(g) One and two tailed tests(h) Tests on mean and variance from samples under different assumptions and knowledge of the underlying distribution; 6. Regression Analysis and Hypothesis Testing(a) OLS estimates(b) Assumptions and proof of BLUE(c) Detection, effect, and remedy of multicollinearity(d) Detection, effect, and remedy ofheteroskedasticity(e) Detection, effect, and remedy of autocorrelation(f) Misspecification errors and regression model building(g) Hypothesis testing onOLS estimates(h) GIS(i) Comparison of regression modelU) Use of dummy independent variables(k) Robust regression and effect of outliers; 7. Miscellaneous Topics(a) Fitting theoretical distributions to observed frequency distributions (b) Tests of goodness off it (chisquare test, Kolmogorov Smirnov test) (c) Identification of outliers(d) Cluster analysis; 8. Practical applications with (Civil) engineering data. **Course Reference**: 1. Experimentation and Uncertainty Analysis: Hugh M. Coleman and W.G. Steele; 2. Handbook of statistical Methods for Scientists and Engineers: H.M. Wadsworth; 3. Statistical Treatment of Experimental Data: J.R. Green and D. Margerison; 4. Basic Econometrics: Damodar Gujarati
CE602	ADVANCED MATHEMATICS FOR CIVIL ENGINEERS	3-0-0--4	Linear differential equations; Fourier integrals and transforms; Partial differential equations; Numerical methods in general; Numerical methods for differential equations; Linear algebra; Numerical methods in linear algebra; Data analysis, Probability theory; Mathematical statistics.
CE602A	ADVANCED MATHEMATICS FOR CIVIL ENGINEERS	3-0-0-0-9	Linear differential equations; Fourier integrals and transforms; Partial differential equations; Numerical methods in general; Numerical methods for differential equations; Linear algebra; Numerical methods in linear algebra; Data analysis, Probability theory; Mathematical statistics.
CE602N	ADVANCED MATHEMATICS FOR CIVIL ENGINEERS	3-0-0--4	Linear differential equations; Fourier integrals and transforms; Partial differential equations; Numerical methods in general; Numerical methods for differential equations; Linear algebra; Numerical methods in linear algebra; Data analysis, Probability theory; Mathematical statistics.

CE603A	MATHEMATICS FOR CIVIL ENGINEERS		Linear Differential Equations: Homogeneous Linear Equations of Second Order; Second Order Homogeneous Equations with Constant Coefficients; Case of Complex Roots, Complex Exponential Function; Nonhomogeneous Equations; Solution by Undetermined Coefficients; Solution by Variation of Parameters Fourier Integrals and Transforms: Fourier Integrals; Fourier Cosine and Sine Transforms; Fourier Transform andProperties; Dirac Delta Function; Convolution Theorem; Parseval's Theorem; Fourier integral to Laplace transform Partial Deerential Equations: Basic Concepts; Modeling: Vibrating String, Wave Equation; Separation of Variables,Use of Fourier Series; Modeling: Membrane, Two Dimensional Wave Equation; Rectangular Membrane, Use ofDouble Fourier SeriesLinear Algebra: Rank of a Matrix, Linear Independence, Vector Space; Solutions of Linear Systems: Existence,Uniqueness, General Form; Vector Spaces, Inner Product Spaces, Linear Transformations; Eigenvalues,Eigenvectors; Similarity of Matrices, Basis of Eigenvectors, Diagonalization
CE606A	OPTIMIZATION METHODS FOR CIVIL ENGINEERS	3-0-0-0-5	Introduction to the course and its importance. Optimization methods: problem formulation, solution techniques for linear and integer problems (both unconstrained and constrained), sensitivity analysis. Brief introduction to nonlinear problems. Introduction to nontraditional optimization methods. Case studies from Civil Engineering. **Course Reference**: 1. Deb K, Optimization for Engineering Design: Algorithms and Examples, PHI, Second Edition; 2. Rao, S.S. Engineering Optimization: Theory and Practice, 4th Edition, Wiley; 3. Hamdy A. Taha. Operations Research: An Introduction. McMillan; 4. Richard de Neufville. Applied Systems Analysis. McGraw Hill; 5. Chong, E. K.P. and Zak, S. H. An Introduction to Optimization: Second Edition, Wiley Student Edition. 01-APR-2016
CE610	ADVANCED HYDROLOGY	3-0-0-0-4	Hydrologic cycle, systems concept, hydrologic model classification; Reynold's Transport Theorem, continuity, momentum, and energy equations; Atmospheric hydrology:atmospheric circulation, water vapor, formation and forms of precipitation, precipitable water, monsoon characteristics in India, Thunderstorm Cell model, IDF relationships; factors affecting evaporation, estimation and measurement of evaporation, energy balance method,aerodynamic method, Priestley Taylor method, and pan evaporation; Surface Water:Catchment storage concept, Hortonian and saturation overland flow, streamflow hydrographs,baseflow separation, index, ERH & DRH, algorithm for abstraction using Green Ampt equation, SCS method, overland and channel flow modeling, time area concepts, and stream networks; Unit Hydrograph: General hydrologic system model, response functions of a linearhydrologic systems and their

			interrelationships, convolution equation; definition and limitations of a UH; UH derivation from single and complex storms; UH optimization using regression, matrix, and LP methods; Synthetic unit hydrograph, SCurve, IUH; Subsurface Water: Soil moisture, porosity, saturated and unsaturated flow; Richards; equation,infiltration, Horton's, Philip's, and Green Ampt methods, parameter estimation, ponding timeconcepts; Groundwater Hydrology: Occurrence of groundwater, aquifers & their properties,Darcy's law, permeability, transmissibility, stratification, confined groundwater flow,unconfined groundwater flow under Dupit's assumptions; Well hydraulics, steady flow intoconfined and unconfined wells; Unsteady flow in a confined aquifer.
CE610A	ADVANCED HYDROLOGY	3-0-0-0-9	Hydrologic cycle, systems concept, hydrologic model classification; Reynold'sTransport Theorem, continuity, momentum, and energy equations; Atmospheric hydrology:atmospheric circulation, water vapor, formation and forms of precipitation, precipitable water, monsoon characteristics in India, Thunderstorm Cell model, IDF relationships; factors affecting evaporation, estimation and measurement of evaporation, energy balance method,aerodynamic method, Priestley Taylor method, and pan evaporation; Surface Water:Catchment storage concept, Hortonian and saturation overland flow, streamflow hydrographs,base flow separation, index, ERH & DRH, algorithm for abstraction using Green Ampt equation, SCS method, overland and channel flow modeling, time area concepts, and stream networks; Unit Hydrograph: General hydrologic system model, response functions of a linear hydrologic systems and their interrelationships, convolution equation; definition and limitations of a UH; UH derivation from single and complex storms; UH optimization using regression, matrix, and LP methods; Synthetic unit hydrograph, SCurve, IUH; Subsurface Water: Soil moisture, porosity, saturated and unsaturated flow; Richard's equation,infiltration, Horton's, Philip's, and Green Ampt methods, parameter estimation, ponding timeconcepts; Groundwater Hydrology: Occurrence of groundwater, aquifers & their properties,Darcy's law, permeability, transmissibility, stratification, confined groundwater flow,unconfined groundwater flow under Dupit's assumptions; Well hydraulics, steady flow intoconfined and unconfined wells; Unsteady flow in a confined aquifer. 21-JUL-2014
CE611A	ADVANCED HYDRAULICS	3-0-0-0-9	Basics: dimensional analysis, equations of continuity, motion, and energy, irrotational flow, drag and lift of immersed bodies; Pipe flow: laminar flow, turbulent flow, boundary layer theory, wall turbulent shear flow, free turbulent shear flow; Open Channel flow: energy depth relationships, uniform flow, gradually varied flow, hydraulic jump, rapidly varied flow, spatially varied flow

			unsteady flow.
CE611N	ENGINEERING HYDRAULICS	3-0-0--4	Basics: dimensional analysis, equations of continuity, motion, and energy, irrotational flow, drag and lift of immersed bodies; Pipe flow: laminar flow, turbulent flow, boundary layer theory, wall turbulent shear flow, free turbulent shear flow; Open Channel flow: energydepth relationships, uniform flow, gradually varied flow, hydraulic jump, rapidly varied flow, spatially varied flow, unsteady flow.
CE612	FLUID MECHANICS LABORATORY	2-0-3-0-4	Verification of momentum equation; Friction loss in pipes; Rainfall runoff relationship; Flow over sharp crested weir; Flow in pipe networks; Bernoulli theorem; Fall velocity of objects; Point velocity measurement by ADV; Reynolds apparatus; Venturimeter and orifice meter; Energy loss in bends; Ground waterflow/ well abstraction; Hydrogen bubble flow visualization; Hydraulic jump; Flowpast a cylinder
CE612A	FLUID MECHANICS LABORATORY	2-0-3-0-9	Verification of momentum equation; Friction loss in pipes; Rainfall runoff relationship; Flow over sharp crested weir; Flow in pipe networks; Bernoulli theorem; Fall velocity of objects; Point velocity measurement by ADV; Reynolds apparatus; Venturimeter and orifice meter; Energy loss in bends; Ground water flow/ well abstraction; Hydrogen bubble flow visualization; Hydraulic jump; Flow past a cylinder.
CE612N	FLUID MECHANICS LABORATORY	2-0-3-0-4	Verification of momentum equation; Friction loss in pipes; Rainfall runoff relationship; Flow over sharp crested weir; Flow in pipe networks; Bernoulli theorem; Fall velocity of objects; Point velocity measurement by ADV; Reynolds apparatus; Venturimeter and orifice meter; Energy loss in bends; Ground waterflow/ well abstraction; Hydrogen bubble flow visualization; Hydraulic jump; Flowpast a cylinder
CE613	COMPUTER METHODS IN HYDRAULICS AND HYDROLOGY	2-0-3-0-4	Basic: Introduction to computer programming and computation with Matlab. (02 lectures) Open channel flow: Estimation of normal and critical depth; uniform flow computations; computation ofwater surface profile (WSP) gradually varied flow estimation using standard step and direct stepmethods, WSP in presence of hydraulic structures; unsteady flow SaintVenant equation, kinematic wave routing, diffusion routing, overland flow; steady and unsteady modelling using HECRAS. (07 lectures) Closed conduit flow: Steady and unsteady state modelling; pipe network analysis; introduction toEPANET/WaterCAD. (05 lectures) Surface water hydrology: Estimation of Unit hydrographs; lumped and distributed flow routing; hydrologic statistics parameter estimation, time series analysis, frequency analysis, geostatistics; hydrologic modelling using HECHMS. (05 lectures) Groundwater hydrology: Solving groundwater flow equation saturated and unsaturated flow, Richard’s equation, GreenAmpt infiltration model; introduction to MODFLOW. (05 lectures) Application of soft computing

			methods and GIS in Hydraulic and Hydrologic modelling. (03 lectures) Laboratory: Programming exercises for the related topics. (I 0 lab classes) **Course Reference**: 1. Chow V.T., Maidment D.R. and Mays L.W. (1988), Applied Hydrology, McGrawHill; 2. Chaudhry M.H. (2007), OpenChannel Flow, 2nd Edition, Springer; 3. Deb K. (1995), Optimization for engineering design: Algorithm and examples, Prentice Hall India; 4. Heywood I., Cornelius S. and Carver S. (2006), An Introduction to Geographical InformationSystems, 3rd Edition, Prentice Hall; 5. Mathews J.H. and Fink K.D. (2006), Numerical Methods using Matlab, 4th Edition, Prentice Hall; 6. Press eta!., Numerical Recipes (C, C++, FORTRAN or Pascal), Cambridge University Press; 7. Todd O.K. and Mays L.W. (2008), Groundwater Hydrology, 3rd Edition, John Wiley & Sons; 8. Wasserman P.O. (1989), Neural computing, theory and practice, Van Nostrand Reinhold, New York
CE613A	COMPUTER METHODS IN HYDRAULICS AND HYDROLOGY	2-0-3-0-9	Basic: Introduction to computer programming and computation with Matlab. (02 lectures) Open channel flow: Estimation of normal and critical depth; uniform flow computations; computation ofwater surface profile (WSP) gradually varied flow estimation using standard step and direct step methods, WSP in presence of hydraulic structures; unsteady flow Saint Venant equation, kinematic wave routing, diffusion routing, overland flow; steady and unsteady modelling using HECRAS. (07 lectures) Closed conduit flow: Steady and unsteady state modelling; pipe network analysis; introduction to EPANET/WaterCAD. (05 lectures) Surface water hydrology: Estimation of Unit hydrographs; lumped and distributed flow routing; hydrologic statistics parameter estimation, time series analysis, frequency analysis, geostatistics; hydrologic modelling using HECHMS. (05 lectures) Groundwater hydrology: Solving groundwater flow equation saturated and unsaturated flow, Richards equation, GreenAmpt infiltration model; introduction to MODFLOW. (05 lectures) Application of soft computing methods and GIS in Hydraulic and Hydrologic modelling. (03 lectures) Laboratory: Programming exercises for the related topics. (I 0 lab classes) **Course Reference**: 1. Chow V.T., Maidment D.R. and Mays L.W. (1988), Applied Hydrology, McGrawHill2. Chaudhry M.H. (2007), OpenChannel Flow, 2nd Edition, Springer; 3. Deb K. (1995), Optimization for engineering design: Algorithm and examples, Prentice Hall India; 4. Heywood I., Cornelius S. and Carver S. (2006), An Introduction to Geographical InformationSystems, 3rd Edition, Prentice Hall; 5. Mathews J.H. and Fink K.D. (2006), Numerical Methods using Matlab, 4th Edition, Prentice Hall; 6. Press eta!., Numerical Recipes (C, C++, FORTRAN or Pascal), Cambridge University Press; 7. Todd O.K. and Mays L.W. (2008), Groundwater Hydrology, 3rd Edition, John Wiley & Sons; 8.

			Wasserman P.O. (1989), Neural computing, theory and practice, Van Nostrand Reinhold, New York.
CE614	STOCHASTIC HYDROLOGY	3-0-0-0-4	The hydrologic processes: precipitation, evaporation, infiltration, groundwater,and stream flow; Hydrologic measurements and networks; Analysis of discreteand continuous hydrologic data: harmonic analysis, statistical analysis includingfrequency analysis, correlation, and regression analysis and multivariate analysis,time series analysis and its applications; System analysis and synthesis; Linearand non linear, lumped and distributed parameter systems; Queing models,simulation analysis; Hydrologic design of water resources systems.
CE614A	STOCHASTIC HYDROLOGY	3-0-0-0-9	Statistical methods in hydrology, probability distribution of hydrologic variables, hypothesis testing and goodness of fit, flood frequency analysis, single and multiple regression analysis, classification of time series, characteristics of hydrologic time series, statistical principles and techniques for hydrologic time series modelling, time series modelling of annual and periodic hydrologic time series (including AR, ARMA, ARIMA, and DARMA models), multivariate modelling of hydrologic time series, practical considerations in time series modelling applications.
CE615	INTRODUCTION AI TECHNIQUES	3-0-0-0-4	Expert Systems (ES): history of ES, basic concepts of ES, definition and components of ES, inference engines and reasoning mechanisms e.g. forward reasoning, backward reasoning, and mixed reasoning, knowledge representation methods and development of the rule based knowledge base, dealing with uncertainty, and selected case studies of ES applications to engineering and sciences; Artificial Neural Networks (ANNs): background and history of ANNs, definitions and basic concepts of ANNs, biological and artificial neural networks, feedforward and feedback networks, supervised and unsupervised learning methodsstandard backpropagation (BP), conjugate gradients BP, self organizing networks, etc., development of ANN models for specific problems and selected case studies; Genetic Algorithms (GAs): fundamentals and preliminary concepts of evolution and GA, preliminaries of optimization, genetic operatorsselection, crossover, and mutation, binary and realcoded GAs, constraint handling in GAs, and selected case studies involving GA applications to engineering.
CE616	SEDIMENT TRANSPORTATION	3-0-0-0-4	Properties of sediment, incipient motion, bed load, suspended load, totalload, sediment measurements, regime concept, bed form mechanics, plan formand stream bed variations of rivers, reservoir sedimentation, erosion and deposition, sediment control, sediment transport in pipes.
CE616A	SEDIMENT TRANSPORTATION	3-0-0-0-9	Properties of sediment, incipient motion, bed load, suspended load, total load, sediment measurements, regime concept, bed form mechanics, plan formand

			stream bed variations of rivers, reservoir sedimentation, erosion and deposition, sediment control, sediment transport in pipes. 25-jul-14
CE619	ECOHYDROLOGY	3-0-0-0-4	Introduction: Origin and scope of ecohydrology. (03 Lectures) Ecohydrological processes: Interactions between physical, chemical and biological processesat basin scale soil water dynamics, land surface energy budgets; scales of interactions; ecohydrological optimality theory; ecohydrological controls on nutrient cycle; Landscapeconnectivity morphological, ecological and hydrological connections. (12 Lectures) Techniques in ecohydrological measurements: Measuring energy and water fluxes in atmosphere, soil and vegetation; atmosphere latent, sensible and C02 fluxes, distribution ofwind, temperature and humidity; soil soil moisture, soil respiration and soil heat flux; vegetation leaf area index, stomatal conductance and transpiration. (08 Lectures) Ecohydrological modelling: Governing equations; mathematical models stochastic and deterministic models; process based and empirical models; calibration and validation ofmodels; scale issues in ecohydrological modelling. (10 Lectures) Applications of ecohydrology: Use of ecohydrogical principles in paleohydrology and climatechange studies; ecohydrological approach for sustainable management of floods anddroughts; case studies from tropical river basins and dry land ecosystems. (08 Lectures) **Course Reference**: 1. Odorico P., Porporato A. 2006. Dry/and Ecohydrology, Springer, Dordrecht, The Netherlands; 2. Eagleson P.S. 2002. Ecohydrology: Darwinian expression of vegetation form and fimction, Cambridge University Press, Cambridge, UK; 3. Harper D., Zalewski M., Pacini N. 2008. Ecohydrology: processes, models and casestudies: An approach to the sustainable management of water resources, CABInternational, Cromwell Press, Trowbridge, UK; 4. Rodriguezlturbe 1., Porporato A. 2005. Ecohydrology of watercontrolled ecosystems: soil moisture and plant dynamics, Cambridge University Press, Cambridge, UK; 5. Wood P.J., Hannah D.M., Sadler J.P. 2007. Hydroecology and Ecohydrology: past, present andfitture, John Wiley & Sons, Chichester, UK.
CE620	STRUCTURAL DYNAMICS	3-0-0--4	Loading: nature of dynamic loading, harmonic, random, types of dynamic loading; Continuous systems: rods (axial vibrations), beams (shear, axial and axial shear flexural vibrations); Discrete mass systems: SDOF (free and forced vibrations), MDOF (generalized coordinates, eigenvalue analysis, matrix and modal timehistory analysis); Introduction of random vibration: stochastic processes, stochastic analysis of linear dynamical systems to Gaussian inputs, SDOF, MDOF.
CE620A	STRUCTURAL DYNAMICS	3-0-0-0-9	Loading: nature of dynamic loading, harmonic, random, types of dynamic loading; Continuous systems: rods (axial vibrations), beams (shear, axial and axial shear

			flexural vibrations); Discrete mass systems: SDOF (free and forced vibrations), MDOF (generalized coordinates, eigen value analysis, matrix and modal timehistory analysis); Introduction of random vibration: stochastic processes, stochastic analysis of linear dynamical systems to Gaussian inputs, SDOF, MDOF.
CE621	Engineering Mechanics	3-0-0-4-4	Stress analysis: forces and moments, theory of stress, principal stresses andstress invariants, compatibility equations, equilibrium equations; Strain: deformation and velocity gradients, Lagrangian and Eulerian description andfinite strain, small deformation theory, principal strains and strain invariants,compatibility conditions; Fundamental physical principles: conservation of mass,linear momentum, angular momentum, and energy, second law of thermodynamics; Constitutive theory: St. Venants principal, linear elasticity and generalized Hooks law, Stokesian and Newtonian fluids, Navier Stokes equations, Bernoulli equation, linear visco elasticity, yield criteria; Applications: Airy stress function,two dimensional elastostatics problems, torsion.
CE621A	ENGINEERING MECHANICS	3-0-0-0-9	Stress analysis: forces and moments, theory of stress, principal stresses andstress invariants, compatibility equations, equilibrium equations; Strain:deformation and velocity gradients, Lagrangian and Eulerian description andfinite strain, small deformation theory, principal strains and strain invariants,compatibility conditions; Fundamental physical principles: conservation of mass,linear momentum, angular momentum, and energy, second law of thermodynamics;Constitutive theory: St. Venants principal, linear elasticity and generalized Hooks law, Stokesian and Newtonian fluids, NavierStokes equations, Bernoulli equation, linear viscoelasticity, yield criteria; Applications: Airy stress function,two dimensional elastostatics problems, torsion.
CE621N	ENGINEERING MECHANICS	3-0-0--4	Stress analysis: forces and moments, theory of stress, principal stresses andstress invariants, compatibility equations, equilibrium equations; Strain:deformation and velocity gradients, Lagrangian and Eulerian description andfinite strain, small deformation theory, principal strains and strain invariants, compatibility conditions; Fundamental physical principles: conservation of mass,linear momentum, angular momentum, and energy, second law of thermodynamics;Constitutive theory: St. Venants principal, linear elasticity and generalized Hooks law, Stokesian and Newtonian fluids, NavierStokes equations, Bernoulli equation, linear viscoelasticity, yield criteria; Applications: Airy stress function,two dimensional elastostatics problems, torsion.
CE622	Stability of Structures	3-0-0-4-4	Criteria for Design of Structures: Stability, Strength, and Stiffness Classical Concept of Stability of Discrete Systems: Linear and nonlinear behaviour Stability of Continuous Systems: Stability of Columns: axial flexural buckling, lateral bracing of columns, combined axial

			flexural torsion buckling. Stability of Frames: member buckling versus global buckling, slenderness ratio of frame members. Stabilityof Beams: lateraltorsion buckling. Stability of Plates: axial flexural buckling, shear flexural buckling, buckling under combined loadsIntroduction to Inelastic Buckling and Dynamic Stability
CE622A	STABILITY OF STRUCTURES	3-0-0-0-9	Criteria for design of structures: stability, strength, and stiffness; Classical concept of stability; Stability of discrete systems: linear and nonlinear behaviour;Stability of continuous systems: stability of columns: axialflexural buckling,lateral bracing of columns, combined axial flexural torsion buckling; Stabilityof frames: member buckling versus global buckling, slenderness ratio of frame members; Stability of beams: lateraltorsion buckling; Stability of plates: axial flexural buckling, shear flexural buckling, buckling under combined loads;Introduction to inelastic buckling and dynamic stability.
CE622N	STABILITY OF STRUCTURES	3-0-0--4	Criteria for design of structures: stability, strength, and stiffness; Classical concept of stability; Stability of discrete systems: linear and nonlinear behaviour;Stability of continuous systems: stability of columns: axialflexural buckling,lateral bracing of columns, combined axial flexural torsion buckling; Stability of frames: member buckling versus global buckling, slenderness ratio of framemembers; Stability of beams: lateral torsion buckling; Stability of plates: axial flexural buckling, shear flexural buckling, buckling under combined loads;Introduction to inelastic buckling and dynamic stability.
CE623	EXPERIMENTAL METHODS IN STRUCTURL ENGINEERING	2-0-3-0-4	Similitude and Structural Models: Dimensional analysis, Buckingham’s Pi theorem, Scale factors and dynamic similitude Uses and Applications of Models: Types of model investigation, Indirect and direct models, Elastic and Inelastic Models (steel, concrete and masomy), size effects, Analysis of Experimental Data: Error and uncertainty in experiment, Measurement systems, Accuracy in models and reliability of resultsTest Planning, Design and Implementation: Testing sequence and experimental plan, Loading systems, devices, actuators and their control, etc.Instrumentation: Mechanical, electrical, electronic system and their calibration, various types of sensors for displacement, velocity, acceleration, pressure, loads, strains, etc, fullfield measurements, .Data Acquisition System and Data Processing: Analog systems, digital systems using personal computers, dynamic measurement, numerical and graphical data processing and archiving Lab Exercises: Experiments to illustrate buckling of stiUctural members; loaddefb1mation behaviour of beams, columns, joints, and fiames under various loads; mode shapes, natural frequency, damping factors fiom free andforced vibrations, shake table tests, etc.

			Course Reference: 1. Dally, J. W. and Riley, W. F. (1978). Experimental Stress Analysis, McGraw HillHarris H. G. and Sabnis, G. M. (1999); 2. Structural Modeling and Experimental Techniques, CRC Press 1999, Nachtigal, C.L. (I990); 3. Jnstrumentation and Control, Wiley & Sons, 1990Reese, R. T. and Kawahara, W. A. (1993); 4. Handbook of Structural Testing, Prentice Hall I Fairmont PressHolman, J. P. (200 I). Experimental Methods for Engineers, McGraw Hill
CE623A	EXPERIMENTAL METHODS IN STRUCTURL ENGINEERING	2-0-3-0-9	Similitude and Structural Models: Dimensional analysis, Buckingham's Pi theorem, Scale factors and dynamicsimilitudeUses and Applications of Models: Types of model investigation, Indirect and direct models, Elastic and Inelastic Models (steel, concrete and masomy), size effects Analysis of Experimental Data: Error and uncertainty in experiment, Measurement systems, Accuracy in models and reliability of results.Test Planning, Design and Implementation: Testing sequence and experimental plan, Loading systems, devices, actuators and their control, etc.Instrumentation: Mechanical, electrical, electronic system and their calibration, various types of sensors for displacement, velocity, acceleration, pressure, loads, strains, etc, fullfield measurements, Data Acquisition System and Data Processing: Analog systems, digital systems using personal computers, dynamic measurement, numerical and graphical data processing and archiving Lab Exercises: Experiments to illustrate buckling of structural members; load deformation behaviour of beams, columns, joints, and fiames under various loads; mode shapes, natural frequency, damping factors fiom free and forced vibrations, shake table tests, etc.
CE623N	EXPERIMENTAL METHODS IN STRUCTURAL ENGINEERNIG	2-0-3--4	Similitude and Structural Models: Dimensional analysis, Buckingham's Pi theorem, Scale factors and dynamic similitude Uses and Applications of Models: Types of model investigation, Indirect and direct models, Elastic and Inelastic Models (steel, concrete and masomy), size effects Analysis of Experimental Data: Error and unce1tainty in experiment, Measurement systems, Accuracy in models and reliability of results Test Planning, Design and Implementation: Testing sequence and experimental plan, Loading systems, devices, actuators and their control, etc.Instrumentation: Mechanical, electrical, electronic system and their calibration, various types of sensors for displacement, velocity, acceleration, pressure, loads, strains, etc, fullfield measurements. Data Acquisition System and Data Processing: Analog systems, digital systems using personal computers, dynamic measurement, numerical and graphical data processing and archivingLab Exercises: Experiments to illustrate buckling of structural members; load deformation behaviour of beams, columns, joints, and fiames under various loads; mode

			shapes, natural frequency, damping factors fiom free andforced vibrations, shake table tests, etc. **Course Reference**: 1. Dally, J. W. and Riley, W. F. (1978). Experimental Stress Analysis, McGraw Hill; 2. Harris H. G. and Sabnis, G. M. (1999). Structural Modeling and Experimental Techniques, CRC Press 1999Nachtigal, C.L. (I990); 3. Jnstrumentation and Control, Wiley & Sons, 1990Reese, R. T. and Kawahara, W. A. (1993); 4. Handbook of Structural Testing, Prentice Hall I Fairmont PressHolman, J. P. (200 I). Experimental Methods for Engineers, McGraw Hill
CE625	MASONARY STRUCTURES	3-0-0-0-4	Properties of constituents: units burnt clay, concrete blocks, mortar, grout,reinforcement; Masonry bonds and properties: patterns, shrinkage, differential movement, masonry properties compression strength ; Stresses in masonry walls: vertical loads, vertical loads and moments eccentricity & kern distance,lateral loads inplane, outof plane; Behaviour of masonry walls and piers:axial and flexure, axial shear and flexure, Behaviour of Masonry Buildings: unreinforced masonry buildings importance of bands and corner & vertical reinforcement, reinforced masonry buildings cyclic loading & ductility of masonry walls; Behaviour of masonry infills in RC frames: strut action; Structural design of masonry in buildings: methods of design WSD, USD, seismic design seismic loads, code provisions, infills, connectors, ties; Seismic evaluationand strengthening of masonry buildings: methods insitu, nonde constructive testing; Construction practices and new materials.
CE625A	MASONARY STRUCTURES	3-0-0-0-9	Properties of constituents: units burnt clay, concrete blocks, mortar, grout,reinforcement; Masonry bonds and properties: patterns, shrinkage, differential movement, masonry properties compression strength ; Stresses in masonrywalls: vertical loads, vertical loads and moments eccentricity & kern distance,lateral loads inplane, outofplane; Behaviour of masonry walls and piers:axial and flexure, axial shear and flexure, Behaviour of Masonry Buildings:unreinforced masonry buildings importance of bands and corner & verticalreinforcement, reinforced masonry buildings cyclic loading & ductility of masonry walls; Behaviour of masonry infills in RC frames: strut action; Structural design of masonry in buildings: methods of design WSD, USD, seismic design seismic loads, code provisions, infills, connectors, ties; Seismic evaluation and strengthening of masonry buildings: methods insitu, non-destructive testing; Construction practices and new materials.
CE627	ADVANCED DESIGN OF STEEL STRUCTURES	3-0-0-0-4	Properties of steel: mechanical properties, hysteresis, ductility; HotRolled Sections: compactness and noncompactness, slenderness, residual stresses;Design of steel structures: inelastic bending curvature, plastic moments, design criteria stability , strength, drift; Stability criteria: stability of beams local buckling of compression

			flange & web, lateral torsional buckling, stability of columns slenderness ratio of columns, local buckling of flanges and web,bracing of column about weak axis, method of design allowable stress design,plastic design, load and resistance factor design; Strength Criteria: beams flexure, shear, torsion, columns moment magnification factor, effective length,PM interaction, biaxial bending, joint panel zones; Drift criteria: P effect,deformation based design; Connections: types welded, bolted, location beamcolumn,column foundation, splices.
CE628	DURABILITY OF CONCRETE STRUCTURES	3-0-0-0-4	Concrete and the environment: interaction; Overview of concrete deterioration: alkali aggregate reaction, corrosion, carbonation; Permeability of concrete andits measurement: penetration of carbon dioxide and chlorides into concrete,corrosion of steel in concrete electrochemistry of corrosion, micro and macrocell corrosion, corrosion cells and currents, role of concrete, prevention ofcorrosion; Corrosion induced longitudinal cracks: nature and properties of corrosion products; Alkali aggregate reaction: reactive minerals, mechanism of deterioration, identification and tests; Codal provisions for durability; Nondestructive testing; repair/rehabilitation of structures.
CE628A	DURABILITY OF CONCRETE STRUCTURES	3-0-0-0-9	Concrete and the environment: interaction; Overview of concrete deterioration:alkali aggregate reaction, corrosion, carbonation; Permeability of concrete andits measurement: penetration of carbon dioxide and chlorides into concrete, corrosion of steel in concrete electrochemistry of corrosion, micro and macrocell corrosion, corrosion cells and currents, role of concrete, prevention ofcorrosion; Corrosion induced longitudinal cracks: nature and properties of corrosion products; Alkali aggregate reaction: reactive minerals, mechanism of deterioration, identification and tests; Codal provisions for durability; Nondestructive testing; repair/rehabilitation of structures.
CE629	EARTHQUAKE ANALYSIS AND DESIGN OF STRUCTURES	3-0-0--4	Characteristics of earthquakes; Earthquake response of structures; Concept of earthquake resistant design; Code provisions of design of buildings; Design ofliquid storage tanks; Liquefaction; Nonengineered construction; Special topics: bridges, dams, strengthening of existing buildings.
CE629A	EARTHQUAKE ANALYSIS AND DESIGN OF STRUCTURES	3-0-0-0-9	Characteristics of earthquakes; Earthquake response of structures; Concept ofearthquake resistant design; Code provisions of design of buildings; Design ofliquid storage tanks; Liquefaction; Nonengineered construction; Special topics: bridges, dams, strengthening of existing buildings.
CE630	ROCK MECHANICS	3-0-0--4	Physical properties and classification of intact rock and rock masses, rockexploration, engineering properties of rock, stresses in rock near underground openings; Rock tunneling, rock slope stability, bolting, blasting, grouting androck foundation design.
CE630A	ROCK MECHANICS	3-0-0-0-9	Physical properties and classification of intact rock and

			rock masses, rockexploration, engineering properties of rock, stresses in rock near underground openings; Rock tunneling, rock slope stability, bolting, blasting, grouting androck foundation design.
CE631	ADVANCED GEOTECHNICAL ENGINEERING	3-0-0-4-4	Soil composition and soil structure, Steady State flow, 2D and 3D seepage, Transient flow; Compressibility and Rate of consolidation, One, two, and threedimensional consolidation theories; Shear strength and stressstrain relationships of soils; Stability ofslopes, Arching-effects, Buried Structures.
CE631A	ADVANCED GEOTECHNICAL ENGINEERING	3-0-0-0-9	Soil composition and soil structure, Steady State flow, 2D and 3D seepage, Transient flow; Compressibility and Rate of consolidation, One, two, and threed imensional consolidation theories; Shear strength and stressstrain relationships of soils; Stability ofslopes, Arching- effects, Buried Structures
CE631N	DISCOUNTINUED	3-0-0--4	Soil composition and soil structure, Steady State flow, 2D and 3D seepage, Transientflow; Compressibility and Rate of consolidation, One, two, and threedimensional consolidation theories; Shear strength and stressstrain relationships of soils; Stability ofslopes, Arching-effects, Buried Structures
CE632	FOUNDATION ANALYSIS AND DESIGN	3-0-0-4-4	Settlement and bearing capacity; shallow spread footings, mats, and deep foundations. Foundation models, Contact pressure distribution for footings, Rafts, Piles, Retaining Structures; Soil structure intemction studies; Case studies. Bowles, J. E.: Foundation Analysis and Design (5nd Edition), The McGraw Hill Companies Inc. (2001)
CE632A	FOUNDATION ANALYSIS AND DESIGN	3-0-0-0-9	Settlement and bearing capacity; shallow spread footings, mats, and deep foundations. Foundation models, contact pressure distribution for footings, Rafts, Piles, Retaining Structures; Soilstructure intemction studies; Case studies. Bowles, J. E.: Foundation Analysis and Design (5nd Edition), The McGraw Hill Companies Inc. (2001)
CE632N	FOUNDATION ANALYSIS AND DESIGN	3-0-0-0-4	Settlement and bearing capacity; shallow spread footings, mats, and deep foundations. Foundation models, contact pressure distribution for footings, Rafts, Piles, Retaining Structures; Soilstructure intemction studies; Case studies. Bowles, J. E.: Foundation Analysis and Design (5nd Edition), The McGraw Hill Companies Inc. (2001)
CE633	REINFORCED EARTH STRUCTURES	3-0-0-4-4	Reinforcing materials, Advantage of RE, behaviour of Reinforced earth walls, Soil reinforcement interaction internal and external stability condition, field application of RE. Randomly reinforced earth and analysis of reinforced soils, testing of soil reinforcements Development, fabrication, design, and applications of geotextiles, geogrids, geonets, and geomernbranes. KoemerR. M.: Designing with Geosynthetics (4 u, Edition), Prentice Hall, New Jersey, (1997)

CE634	GROUND IMPROVEMENT TECHNIQUES	3-0-0-4-4	Engineering properties of soft, weak and compressible deposits, principles of treatmen tloading (static and Dynamic), Accelerated flow, Reinforcement, Drainage and fillers, Injections, Thermal, electrical and Chemical Methods Preloading, Dynamic Consolidation, Vertical drains, Granular piles, soil nailing, Anchors, Design Methods and Case histories Moseley and Kirsch: Designing with Geosynthetics (2nd Edition), Routledge, (2004), ISBN: 0415274559
CE634A	GROUND IMPROVEMENT TECHNIQUES	3-0-0-0-9	Engineering properties of soft, weak and compressible deposits; Principles of treatmentloading (static and Dynamic); Accelerated flow; Reinforcement; Drainage and filters, Injections, thermal, electrical and Chemical Methods; Preloading; Dynamic Consolidation; Vertical drains; Granular piles; Soil nailing; Anchors; Design methods and case studies.
CE634N	GROUND IMPROVEMENT TECHNIQUES	3-0-0--4	Engineering properties of soft, weak and compressible deposits, principles of treatment loading (static and Dynamic), Accelerated flow, Reinforcement, Drainage and fillers, Injections, Thermal, electrical and Chemical Methods Preloading, Dynamic Consolidation, Vertical drains, Granular piles, soil nailing, Anchors, Design Methods and Case histories Moseley and Kirsch: Designing with Geosynthetics (2nd Edition), Routledge, (2004), ISBN: 0415274559
CE635	FOUNDATION DYNAMICS	3-0-0--4	Dynamics of elastic systems; Single and multidegrees of freedom systems; Empirical and semiempirical approaches to the theory of soil dynamics; Elastic theories of soil dynamics; Wave propagation; Dynamic soil properties; Design of machine foundations; Vibration isolation; Pile dynamics.
CE635A	FOUNDATION DYNAMICS	3-0-0-0-9	Dynamics of elastic systems; Single and multidegrees of freedom systems; Empirical and semiempirical approaches to the theory of soil dynamics; Elastic theories of soil dynamics; Wave propagation; Dynamic soil properties; Designof machine foundations; Vibration isolation; Pile dynamics.
CE636	GEOTECHNICAL EARTHQUAKE ENGINEERING	3-0-0-0-4	Introduction; Seismic Hazards: Mitigation of Seismic Hazards, seismology and earthquakes, strong ground motion, seismic hazard analysis; Wave propagation in unbounded media: in semiinfinite bodies, in layered soils and attenuation of stress waves; Dynamic soil properties; Ground response analysis; Effect oflocal site conditions on ground motion; Liquefaction: evaluation of liquefaction hazards, effects of liquefaction; Case studies.
CE637	CONSTITUTIVE MODELING OF FRICTIONAL MATERIALS	3-0-0--4	Role of constitutive modeling; Importance of laboratory testing with relationto constitutive modeling; Elasticity: linear, quasi linear, anisotropic; Plasticity basics: yield criteria, flow rule, plastic potential, hardening/softening; Rate Independent Plasticity: mohr Coulomb, nonlinear failure criteria, Drucker Prager, and cap models; Critical state soil mechanics: critical state concept,camclay models, simulation of single element test using camclay,

			consolidation drained and undrained triaxial test; Stressdilatancy theory; Work hardening plasticity theory: formulation and implementation; Applications of elastoplastic models; Special Topics: hypoelasticity plasticity, disturbed state concept.
CE637A	CONSTITUTIVE MODELING OF FRICTIONAL MATERIALS	3-0-0-0-9	Role of constitutive modeling; Importance of laboratory testing with relationto constitutive modeling; Elasticity: linear, quasilinear, anisotropic; Plasticitybasics: yield criteria, flow rule, plastic potential, hardening/softening; Rate Independent Plasticity: mohrCoulomb, nonlinear failure criteria, Drucker Prager, and cap models; Critical state soil mechanics: critical state concept,camclay models, simulation of single element test using camclay, consolidation,drained and undrained triaxial test; Stress dilatancy theory; Work hardening plasticity theory: formulation and implementation; Applications of elastoplastic models; Special Topics: hypoelasticity plasticity, disturbed state concept.
CE638N	GEOTECHNICAL INVESTIGATIONS FOR CIVIL ENGINEERING PROJECTS	2-0-2-0-4	Subsurface exploration planning, drilling and sampling techniques, field andlaboratory tests, instrumentation and monitoring of field data, report preparation.
CE638T	GEOTECHNICAL MEASUREMENTS AND EXPLORATION		Subsurface exploration planning, drilling and sampling techniques, field andlaboratory tests, instrumentation and monitoring of field data, report preparation.
CE639	ANALYTICAL AND NUMERICAL METHODS IN GEOMECHANICS	3----4	Finite difference, finite element and other analytical methods of solution to(i) Elasticity and stability problems in Geomechanics, (ii) Analysis of responseof soil media to applied loads, (iii) Limiting equilibrium, Failure theories, Methodof characteristics, (iv) Limit analysis, etc.
CE642	GEOLOGICAL HAZARDS	3-0-0--4	Geological hazards and environmental impact; Land slides: cause, classification, zonation and protection; Earthquakes: historical seismicity, classification, interplateand intraplate earthquakes, effect on ground structures, magnitude and intensity scales, seismic zonation; Floods: hydrology and types of floods, nature and extentof flood hazard, flood hazard zoning, flood control and protection; Land subsidence; Snow avalanches; Rock bursts; Mapping, monitoring and management of geological hazards.
CE642A	LABORATORY COURSE IN INFRASTRUCTURE ENGINEERING AND MANAGEMENT	3-0-0-0-9	Geological hazards and environmental impact; Landslides: cause, classification, zonation and protection; Earthquakes: historical seismicity, classification, interplateand intraplate earthquakes, effect on ground structures, magnitude and intensity scales, seismic zonation; Floods: hydrology and types of floods, nature and extentof flood hazard, flood hazard zoning, flood control and protection; Land subsidence; Snow avalanches; Rock bursts; Mapping, monitoring and management of geological hazards.
CE645	PHOTOGEOLOGY IN	2-0-2--4	Introduction to physical and structural geology;

	TERRAIN EVALUATION		Landforms and drainage patterns; Elements of photogeology; Stereoscopy; Elementary photo grammetry; Photographic systems, types of cameras, films and filters; Photo interpretation key; Quantitative interpretation of toposheets and airphotos; Applications in engineering geology, landuse, land wastage, hydrogeology, mineral exploration and change detection.
CE646	GLOBAL CLIMATE CHANGE	3-0-0--4	Introduction to global climate; Global climatic models; Methods of reconstructing climate; Quaternary climates, sea level changes, glacial/interglacial cycles; Geological records of climate change, sedimentology, stable isotopes, geochemistry; Geochronology relative and numerical methods; Vegetation dynamics, migration history, response of vegetation to climatic reversals; Prequaternary climates, evolution of climate through geological time.
CE647	PALEOSEISMOLOGY AND TECTONIC GEOMORPHOLOGY	3-0-0--4	Plate tectonic and its relation to earthquakes; Historical and modern seismicity; Mapping of active tectonic landforms in different tectonic environments; Fieldtechniques in paleoseismology, identification of old (prehistoric) earthquake by trenching, estimation of magnitude, slip rates, and recurrence interval of faults,prediction of future earthquake, identification of paleoliquefaction features;Dating techniques; Correlation of paleoseismic data with existing geodetic and geophysical data; Delineation of seismogenic faults and their related seismichazard; Seismic hazard assessment (SHA).
CE651	SPECIAL CONCRETES	3-0-1-0-5	Production & properties of normal concrete : Introduction to portland cement concrete concrete production operations Indian Standard and ACI Mix design of concrete Fresh and hardened properties of concrete Durability of concrete Role of ingredients in concrete Physical and chemical characteristics of pozzolans Role of admixtures and additives in concrete Experimental test parameters and measurements during concrete testing, Special cements : Need Classifications Blended cements, modified hydraulic cements, calcium aluminate cements, calcium sulfate based binders, calcium sulfoaluminate cements, GGBS based cements, shrinkage compensating (or) expansive cements Other special cements: macrodefect free cements, phosphate cements, expansive cements, fastsetting cements, oil well cements Performance and prescriptive specifications, Special concretes : Importance and need high performance concrete and property based classifications. Special concretes: Mass concrete, selfcompacting or selfconsolidating concrete, fiber reinforced concrete, high strength concretes, highvolume fly ash concretes, geopolymer concrete, roller compacting concrete, pervious concrete, light weight concrete, aerated concrete, polymer or polymer modified concretes, ultrahigh performance concretes and others. Mixture proportioning and parameters in the

			development of special concretes. **Course Reference**: 1. Neville, A.M., Properties of concrete, 5th Edition, Pitman Publishers, 1996; 2. Mehta, P.K., and Monteiro P.J.M., Concrete Structure, Properties and Materials, 2nd Edition, PrenticeHall, Inc., 2nd and 3rd Editions (1993 or 2006); 3. Kalousek, G. L. et al, Klein Symposium on Expansive Cement Concretes, 1973; 4. Bapat, J.D., Mineral admixtures in cement and concrete, 2013; 5. High Performance Concrete (Modern Concrete Technology)by PierreClaude Atcin(Aug 25, 1998); 6.High Performance Concrete: From material to structure (Modern Concrete Technology)by Y. Malier(Dec 31, 1990)
CE651A	SPECIAL CONCRETES	3-0-0-0-9	Production & properties of normal concrete : Introduction to portland cement concrete concrete production operations Indian Standard and ACI Mix design of concrete Fresh and hardened properties of concrete Durability of concrete Role of ingredients in concrete Physical and chemical characteristics of pozzolans Role of admixtures and additives in concrete Experimental test parameters and measurements during concrete testing, Special cements : Need Classifications Blended cements, modified hydraulic cements, calcium aluminate cements, calcium sulfate based binders, calcium sulfoaluminate cements, GGBS based cements, shrinkage compensating (or) expansive cements Other special cements: macrodefect free cements, phosphate cements, expansive cements, fastsetting cements, oil well cements Performance and prescriptive specifications, Special concretes : Importance and need high performance concrete and property based classifications. Special concretes: Mass concrete, selfcompacting or selfconsolidating concrete, fiber reinforced concrete, high strength concretes, high volume fly ash concretes, geopolymer concrete, roller compacting concrete, pervious concrete, light weight concrete, aerated concrete, polymer or polymer modified concretes, ultrahigh performance concretes and others. Mixture proportioning and parameters in the development of special concretes. **Course Reference**: 1. Neville, A.M., Properties of concrete, 5th Edition, Pitman Publishers, 1996; 2.Mehta, P.K., and Monteiro P.J.M., Concrete Structure, Properties and Materials, 2nd Edition, PrenticeHall, Inc., 2nd and 3rd Editions (1993 or 2006); 3. Kalousek, G. L. et al, Klein Symposium on Expansive Cement Concretes, 1973; 4. Bapat, J.D., Mineral admixtures in cement and concrete, 2013; 5. High Performance Concrete (Modern Concrete Technology) by PierreClaude Atcin(Aug 25, 1998); 6. High Performance Concrete: From material to structure (Modern Concrete Technology) by Y. Malier(Dec 31, 1990)
CE671A	INTRODUCTION TO REMOTE SENSING	3-0-2-0-11	Remote sensing system; Physics of remote sensing, EMR characteristics and interaction in atmosphere and

			with ground objects; Sensor types characteristics:types of resolution, FOV, IFOV, PSF; RS satellites and data products; Image processing, interpretation elements; Classification; Geometric and radiometric distortions, Georeferencing, resampling methods; Atmospheric errors and removal; Satellite orbits and characteristics; Applications of optical and microwave remote sensing techniques in Civil Engineering.
CE671N	INTRODUCTION TO REMOTE SENSING	3-0-2--5	Remote sensing system; Physics of remote sensing, EMR characteristics and interaction in atmosphere and with ground objects; Sensor types characteristics:types of resolution, FOV, IFOV, PSF; RS satellites and data products; Image processing, interpretation elements; Classification; Geometric and radiometric distortions, Georeferencing, resampling methods; Atmospheric errors andremoval; Satellite orbits and characteristics; Applications of optical and microwave remote sensing techniques in Civil Engineering.
CE672	MACHINE PROCESSING OF REMOTELY SENSED DATA	3-0-0--4	Image processing system; Preprocessing of remotely sensed data; Radiometric and Geometric distortions and corrections; Image enhancement; Image transformations; Pattern recognition.
CE672A	MACHINE PROCESSING OF REMOTELY SENSED DATA	3-0-0-0-9	Image processing system; Preprocessing of remotely sensed data; Radiometric and Geometric distortions and corrections; Image enhancement; Image transformations; Pattern recognition.
CE673A	INSTRUMENTATION, LABORATORY AND FIELD PRACTICES IN GEOINFORMATICS	0-0-0-0-9	Use of automatic and digital levels, electronic theodolites, total stations, planet abling; Control surveys using GPS, Total station and triangulation methods (adjustment and computations of coordinates); Cartography and report writing.
CE673N	INSTRUMENTATION, LABORATORY AND FIELD PRACTICES IN GEOINFORMATICS	3-0-0--3	Use of automatic and digital levels, electronic theodolites, total stations, planet abling; Control surveys using GPS, Total station and triangulation methods (adjustment and computations of coordinates); Cartography and report writing.
CE674	GLOBAL POSITIONING SYSTEMS (GNSS)	2-0-2-0-4	Global navigation satellite systems(gnss) course details: 1. Overview of GNSS and Introduction to GPS, GLONASS, GALILEO, COMPASS, IRNSS systems. 2. GPS: Basic concepts, signal structure and code modulation Pseudorange measurements and navigation position. 3. Errors and biases in GPS measurements, Accuracy of navigation position: UERE and DOP. Intentional degradation of GPS signals: Selective availability (SA) and Antispoofing (AS), Differential GPS: Space based augmentation systems (e.g., SBAS, GAGAN) and Ground based augmentation systems (e.g., WASS, EGNOS) 4. GPS Carrier Phase measurements: Signal Differencing, Double Differencing and Triple Differencing in GPS measurements. Ambiguity resolution, multi path and other observational errors, Doppler effect on GPS signals, Code and Phase combinations for Ionosphere free, Geometry free,

			Multipath reduction, Ambiguity resolution, Code smoothing, Cycle slip detection and repair. 5. GPS data processing, sequential solutions, Kalman filtering and adjustment computation for GPS. 6. Surveying with GNSS: Point positioning, Relative positioning, Static and Kinematic positioning. Planning and field observations, Networking, Data Post processing, GIS and GPS integration. 7. GNSS applications to Earth Systems, IGS and IERS services. **Course Reference**: 1. Diggelen, Frank van, 2009, AGPS: Assisted GPS, GNSS, and SBAS, Artech House: Boston, pp: 400; 2. Guochang, X., 2007. GPS: Theory, Algorithms and Applications, Springer: Berlin, pp. 355; 3. Hafmann, B., Lichtenegger H. and Collins J., 2001. Global Positioning Systems: Theory and Practice (5th ed), Springer: Berlin, pp. 382; 4. Hafmann, B., Lichtenegger H. and Wasle, E., 2008, GNSS Global Navigation Satelite Systems: GPS, GLONASS, Galileo, and more, Springer: Berlin, pp.546; 5. International Committee on Global Navigation Satelite Systems, 2010, Current and Planned Global and Regional Navigation Satelite Systems and Satelitebased Augmentations Systems, United Nations: NY, pp.70.
CE674A	GLOBAL NAVIGATION SATELLITE SYSTEMS(GNSS)	2-0-2-0-8	1.Overview of GNSS and Introduction to GPS, GLONASS, GALILEO, COMPASS, IRNSS systems. 2. GPS: Basic concepts, signal structure and code modulation Pseudorange measurements and navigation position. 3. Errors and biases in GPS measurements, Accuracy of navigation position: UERE and DOP. Intentional degradation of GPS signals: Selective availability (SA) and Antispoofing (AS), Differential GPS: Space based augmentation systems (e.g., SBAS, GAGAN) and Ground based augmentation systems (e.g., WASS, EGNOS) 4. GPS Carrier Phase measurements: Signal Differencing, Double Differencing and Triple Differencing in GPS measurements. Ambiguity resolution, multi path and other observational errors, Doppler effect on GPS signals, Code and Phase combinations for Ionosphere free, Geometry free, Multipath reduction, Ambiguity resolution, Code smoothing, Cycle slip detection and repair. 5. GPS data processing, sequential solutions, Kalman filtering and adjustment computation for GPS. 6. Surveying with GNSS: Point positioning, Relative positioning, Static and Kinematic positioning. Planning and field observations, Networking, Data Post processing, GIS and GPS integration. 7. GNSS applications to Earth Systems, IGS and IERS services. **Course Reference**: 1. Diggelen, Frank van, 2009, AGPS: Assisted GPS, GNSS, and SBAS, Artech House: Boston, pp: 400; 2. Guochang, X., 2007. GPS: Theory, Algorithms and Applications, Springer: Berlin, pp. 355; 3. Hafmann, B., Lichtenegger H. and Collins J., 2001. Global Positioning Systems: Theory and Practice (5th

			ed), Springer: Berlin, pp. 382; 4. Hafmann, B., Lichtenegger H. and Wasle, E., 2008, GNSS Global Navigation Satelite Systems: GPS, GLONASS, Galileo, and more, Springer: Berlin, pp.546; 5. International Committee on Global Navigation Satelite Systems, 2010, Current and Planned Global and Regional Navigation Satelite Systems and Satelitebased Augmentations Systems, United Nations: NY, pp.70.
CE676	LASER SCANNING AND PHOTOGRAMMETRY	2-0-3-0-4	Altimetric LiDAR: Physics of laser, spectral characteristics of laser, laser interaction with objects; Airborne Altimetric LiDAR: principle: topographic andbathymetric LiDAR, multiple return, full wave digitization; Components of aLiDAR system, INS technology, INSGPS integration, measurement of laser range,calibration; Flight planning; LiDAR geolocation models; Accuracy of various components of LiDAR and error propagation, error analysis of data and errorremoval; Data classification techniques, raw data to bald earth DEM processing,uses of return intensity and full waveform in information extraction, LiDARdata integration with spectral data; LiDAR applications: building, tree, powerline extraction; LiDAR data visualization; Photogrammetry: metric and nonmetric cameras; Geometry of near vertical and tilted photographs, heights andtilt distortions; Rectification and orthophotographs; Stereoscopy, parallax equation and stereo measurements for height determination; Orientation interior,exterior, relative, and absolute, Mathematical model relating image, model and object space; Collinearity and coplanarity conditions, DLT; Image matching techniques; Strip and block triangulation and adjustment; Automatic DTM and Orthophoto production.
CE676A	LASER SCANNING AND PHOTOGRAMMETRY		Altimetric LiDAR: Physics of laser, spectral characteristics of laser, laser interaction with objects; Airborne Altimetric LiDAR: principle: topographic andbathymetric LiDAR, multiple return, full wave digitization; Components of aLiDAR system, INS technology, INSGPS integration, measurement of laser range,calibration; Flight planning; LiDAR geolocation models; Accuracy of variouscomponents of LiDAR and error propagation, error analysis of data and errorremoval; Data classification techniques, raw data to bald earth DEM processing,uses of return intensity and full waveform in information extraction, LiDARdata integration with spectral data; LiDAR applications: building, tree, powerline extraction; LiDAR data visualization; Photogrammetry: metric and nonmetric cameras; Geometry of near vertical and tilted photographs, heights andtilt distortions; Rectification and orthophotographs; Stereoscopy, parallax equationand stereo measurements for height determination; Orientation interior,exterior, relative, and absolute, Mathematical model relating image, model andobject

			space; Collinearity and coplanarity conditions, DLT; Image matching techniques; Strip and block triangulation and adjustment; Automatic DTM and Orthophoto production.
CE677A	GEOSPATIAL DATA PROCESSING		Geodetic reference systems: ICRF and ITRF, Geodetic datums, Earth ellipsoid;basic geometric geodesy; Coordinate systems and transformation; Map projections, geoid and geoidal heights and undulations; Observations and mathematical model, precision and accuracy, rejection of observations, weights and cofactors,correlation and covariance, propagation of errors and variance covariance; Leastsquares adjustment computations; Sequential processing and Kalman Filtering;Variance covariance of adjusted data, error ellipse and error ellipsoid; Statistical analysis of adjusted data; Introduction to GPS; Code and phase measurements; Models for single point positioning and relative positioning using code and phase data; Methods of interpolation; Geostatistical tools: variogram and krigging. 21-JUL-2014
CE677N	GEOSPATIAL DATA PROCESSING		Geodetic reference systems: ICRF and ITRF, Geodetic datums, Earth ellipsoid;basic geometric geodesy; Coordinate systems and transformation; Map projections,geoid and geoidal heights and undulations; Observations and mathematical model, precision and accuracy, rejection of observations, weights and cofactors, correlation and covariance, propagation of errors and variance covariance; Leastsquares adjustment computations; Sequential processing and Kalman Filtering;Variance covariance of adjusted data, error ellipse and error ellipsoid; Statistical analysis of adjusted data; Introduction to GPS; Code and phase measurements; Models for single point positioning and relative positioning using code and phase data; Methods of interpolation; Geostatistical tools: variogram and krigging.
CE678	INTRODUCTION TO GEODESY		Geometric geodesy: DatumsHorizontal & Vertical, GRS80, WGS84, ITRF. Transformation of Coordinates from one datum to another. Mean Sea level, Geoid and MSL in India. Coordinate Systems in Geodesy, Geometry of Ellipsoid, level Surface and Plumb Line, Deflection of vertical, Geoidal Separation, Natural Coordinates, Astrogeodetic deflection.Physical geodesy: Fundamentals of potential theory, Laplace Equation in spherical coordinates, Solution of Laplace Equation, Brun’s formula, Fundamental equation of Physical Geodesy, Stokes; Formula, Gravity, Gravitational Potential and Gravity potential, Anomalous Gravity field, Gravity Anomaly, Gravity reductions: Free Air, Bouger and Isostatic reduction, Earth Gravity Models, Potential number and different height systems. Map Projection: Introduction to Map projection, Purpose and methods of Map projection and their classification. Conformal Map projections LCC and Transverse Mercator Projections.

			Indian Grid System and UTM.Astronomy: Celestial Sphere, Definition of terms in Astronomy, Celestial coordinate systems, Variations in Celestial coordinates. Precession and Nutation. Time systems Sidereal time, Ephemeries time, Atomic time. Rotational Time systems: UT0, UT1, UT2, CIO and Polar motion, Earth Rotation parameters and Leap second. Satellite geodesy: Introduction to Satellite Geodesy, Keplerian Motion, Geometry of ellipse, Kepler ellipse in space, Perturbed satellite motion, Lagrange's and Gaussian form of perturbation equations. Introduction to GNSS satellite systems, Satellite Laser ranging, Satellite Altimetry, VLBI.
CE678A	PHYSICAL GEODESY		Geometric geodesy: DatumsHorizontal & Vertical, GRS80, WGS84, ITRF. Transformation of Coordinates from one datum to another. Mean Sea level, Geoid and MSL in India. Coordinate Systems in Geodesy, Geometry of Ellipsoid, level Surface and Plumb Line, Deflection of vertical, Geoidal Separation, Natural Coordinates, Astrogeodetic deflection.Physical geodesy: Fundamentals of potential theory, Laplace Equation in spherical coordinates, Solution of Laplace Equation, Brun's formula, Fundamental equation of Physical Geodesy, Stokes; Formula, Gravity, Gravitational Potential and Gravity potential, Anomalous Gravity field, Gravity Anomaly, Gravity reductions: Free Air, Bouger and Isostatic reduction, Earth Gravity Models, Potential number and different height systems.Map Projection: Introduction to Map projection, Purpose and methods of Map projection and their classification. Conformal Map projections LCC and Transverse Mercator Projections. Indian Grid System and UTM.Astronomy: Celestial Sphere, Definition of terms in Astronomy, Celestial coordinate systems, Variations in Celestial coordinates. Precession and Nutation. Time systems Sidereal time, Ephemeries time, Atomic time. Rotational Time systems: UT0, UT1, UT2, CIO and Polar motion, Earth Rotation parameters and Leap second. Satellite geodesy: Introduction to Satellite Geodesy, Keplerian Motion, Geometry of ellipse, Kepler ellipse in space, Perturbed satellite motion, Lagrange's and Gaussian form of perturbation equations. Introduction to GNSS satellite systems, Satellite Laser ranging, Satellite Altimetry, VLBI.
CE681A	CHARACTERIZATION OF PAVEMENT MATERIALS		Characterization of pavement materials bituminous mix, aggregates, subgrade, cemented materials and cement concrete; Experimental methods; Basic material modelling, Fatigue and Permanent deformation; Material interphase and interactions; Surface energy concepts; Moisture and temperature sensitivity; Mix design concepts and approaches; Evaluation and useof recycled materials
CE682	ANALYSIS AND DESIGN OF		Introduction to supply and demand sides of transportation engineering, analysisof transportation

	TRANSPORTATION INFRASTRUCTURE		demand (including topics such as category analysis, gravity model, entropy models, choice models, user equilibrium models, etc.). Introduction to public transportation. Designing efficient public transport systems (including topics such as route development, schedule development, pricing strategies, etc.). Concept of structural, functional and drainage design of pavement structure. Design of flexible and rigid pavement various approaches. Cost and reliability considerations. Pavement maintenance issues. Pavement distresses, distress evaluation, maintenance measures, and network level maintenance strategy.
CE682A	ANALYSIS OF PAVEMENT STRUCTURES		Introduction to supply and demand sides of transportation engineering, analysisof transportation demand (including topics such as category analysis, gravitymodel, entropy models, choice models, user equilibrium models, etc.). Introduction to public transportation. Designing efficient public transport systems (including topics such as route development, schedule development, pricing strategies, etc.). Concept of structural, functional and drainage design of pavement structure. Design of flexible and rigid pavement various approaches. Cost and reliability considerations. Pavement maintenance issues. Pavement distresses, distress evaluation, maintenance measures, and network level maintenance strategy.
CE682N	ANALYSIS AND DESIGN OF TRANSPORTATION INFRASTRUCTURE		Introduction to supply and demand sides of transportation engineering, analysis of transportation demand (including topics such as category analysis, gravity model, entropy models, choice models, user equilibrium models, etc.). Introduction to public transportation. Designing efficient public transport systems (includingtopics such as route development, schedule development, pricing strategies, etc.). Concept of structural, functional and drainage design of pavement structure. Design of flexible and rigid pavement various approaches. Cost and reliability considerations. Pavement maintenance issues. Pavement distresses, distress evaluation, maintenance measures, and network level maintenance strategy.
CE683	TRAFFIC ENGINEERING		Microscopic and macroscopic traffic parameters, traffic flow models, car following models, capacity and level of service analysis, design of traffic facilities like unsignalized and signalized intersections, inter changes, express ways, traffic signs, parking areas etc., simulation of traffic streams.
CE683A	TRAFFIC ENGINEERING		Microscopic and macroscopic traffic parameters, traffic flow models, car following models, capacity and level of service analysis, design of traffic facilitieslike unsignalized and signalized intersections, inter changes, express ways, traffic signs, parking areas etc., simulation of traffic streams.
CE684	URBAN		Dimensions of the widening role of urban transportation

	TRANSPORTATIONS SYSTEMS		system planning; the planning process; land use and transport system models; comparison and evaluation of various models; transportation impact study methodologies; strategies for the evaluation of alternative transportation plans and plan implementation; Regional analysis and plan implementation; Regional Analysis and development concepts; the role of transportation planning in the overall regional system; methodology and models for regional transportation system planning; implementation framework and case studies.
CE688	AIRPORT SYSTEMS PLANNING AND DESIGN		Air Transport structure and organization, the challenges and the issues, Forecastingair travel demand trend forecasts and analytical methods; Air freight demand,Characteristics of the aircraft as they affect airport; Airport planning requirements:site selection, layout plan and financial plan; Air traffic control lighting and signing; Airport capacity and configuration; Geometric design of runway, taxiway and aprons; passenger terminal functions, passenger and baggage flow, design concepts, analysis of flow through terminals, parking configurations and apron facilities; Air cargo facilities flow through cargo terminals, unitized systems;Airport drainage and pavement design; Airport access problem; Environmental impact of airports.
CE688A	AIRPORT SYSTEMS PLANNING AND DESIGN		Air Transport structure and organization, the challenges and the issues, Forecasting air travel demand trend forecasts and analytical methods; Air freight demand, Characteristics of the aircraft as they affect airport; Airport planning requirements: site selection, layout plan and financial plan; Air traffic control lighting and signing; Airport capacity and configuration; Geometric design of runway, taxiway and aprons; passenger terminal functions, passenger and baggage flow, design concepts, analysis of flow through terminals, parking configurations and apron facilities; Air cargo facilities flow through cargo terminals, unitized systems; Airport drainage and pavement design; Airport access problem; Environmental impact of airports.
CE689A	CHARACTERIZATION OF PAVEMENT MATERIALS AND ANALYSIS OF PAVEMENTS		Components of a pavement structure. Experimental characterization of pavement materials bituminous mix, aggregates, subgrade, cemented material. Material modeling viscoelastic, viscoplastic behaviour. Load stresses in pavements, generalized multilayer solution Burmister layer, slab, foundation models. Staticand dynamic analysis. Fatigue and rutting modeling and calibration. Temperature stresses in pavements. Estimation of cumulative damage.
CE689N	CHARACTERIZATION OF PAVEMENT MATERIALS AND ANALYSIS OF PAVEMENTS		Components of a pavement structure. Experimental characterization of pavement materials bituminous mix, aggregates, subgrade, cemented material. Material modeling viscoelastic, viscoplastic behaviour. Load stresses in pavements, generalized multilayer solution Burmister layer, slab, foundation models. Staticand

			dynamic analysis. Fatigue and rutting modeling and calibration. Temperature stresses in pavements. Estimation of cumulative damage.
CE690	LABORATORY COURSE IN TRANSPORTATION ENGINEERING		Experiments to characterize pavement materials like, viscosity tests, ageing tests, skid tests, etc. Experiments to characterize bituminous mixes, like mixdesign related experiments, moisture sensitivity related experiments, etc. Experiments related to traffic data collections on speed, volume, travel time, delay, etc. Traffic studio (students will learn to use geometric design softwareand video data analysis software). Demonstrations of various equipments including possible visits to advanced labs and road systems.
CE690A	LABORATORY COURSE IN TRANSPORTATION ENGINEERING		Experimental on road surface characterization Relationship between vscosity and some of its measures Experiments on Bituminous mixed Subgrade improvement techniques for pavement Experiments on traffic flow characterization Computer aided analysis and design techniques in transportation engineering Equiment demonstrator/explanation of worker principle of some equipments relevant to highway industry
CE690N	LABORATORY COURSE IN TRANSPORTATION ENGINEERING		Experiments to characterize pavement materials like, viscosity tests, ageing tests, skid tests, etc. Experiments to characterize bituminous mixes, like mixdesign related experiments, moisture sensitivity related experiments, etc. Experiments related to traffic data collections on speed, volume, travel time, delay, etc. Traffic studio (students will learn to use geometric design softwareand video data analysis software). Demonstrations of various equipmentsincluding possible visits to advanced labs and road systems.
CE698	TECHNICAL PRESENTATION		There will be 14 lectures in the semester on importance of good communication skills,technical writing (notes, papers, thesis, etc.), technical presentation (speed, content visa vis audience, visual and audio aids, development of a talk), ethics, expectations as a listener from a technical talk, formulating questions (as a member ofthe audience) and answers (as the speaker), etc.Each student will be required to present two seminars on a given topic; the first seminar by a student will cover parts of the entire topic. Seminars may also be of varying durations for the same amount of material to be covered. Following each seminar there will be a discussion on the seminar led by the faculty in charge of the course. Each student will also need to submit two reports on the same topic. One will be a short report and the other will be a longer report (like a project report). The objective is for a student to lean how to deliver the same content at various levels of detail (both writing as well as in presentation mode). **Course Reference**: 1. Chambers, H.E. (2001), Effective Communication Skills for Scientific and TechnicalProfessionals, Perseus.Elbow, P. (1981); 2.

			Writing With Power: Techniques for Mastering the Writing Process, Oxford University Press.Stevenson, S. (2002); 3. Strategies for Engineering Communication, John Wiley and Sons. Turk. C. and Kirkman, J. (1989); 4. Effective Writing: Improving Scientific, Technical, andBusiness Communication, Routledge.
CE698A	M.TECH SEMINAR 2		Components of a pavement structure. Experimental characterization of pavement materials bituminous mix, aggregates, subgrade, cemented material. Material modeling viscoelastic, viscoplastic behaviour. Load stresses in pavements, generalized multilayer solution Burmister layer, slab, foundation models. Staticand dynamic analysis. Fatigue and rutting modeling and calibration. Temperature stresses in pavements. Estimation of cumulative damage. 21-JUL-2014
CE699	M. TECH THESIS		M. Tech. Thesis
CE699.	M.TECH THESIS (FOR DUAL DEGREE ONLY)		M.TECH THESIS (FOR DUAL DEGREE ONLY)
CE717	GROUNDWATER HYDROLOGY & POLLUTANT TRANSPORT		Groundwater as a resource, general problems of chemical contamination in groundwater; Fluid potential, hetrogenity and anisotropy; Aquifiers, aquitrads and general geology, well hydraulics, parameter estimation; Steady and transient flow equations, unsaturated flow equation; Pollutant transport in groundwater,chemical and transport processes, numerical modeling and solution, breakthrough curves; Seawater intrusion in coastal aquifiers; Modelling of pollutant transport in the unsaturated zone; Optimization models for management of groundwater quantity and quality; Optimal monitoring network design; Multiple objective management; Conjective management of surface and groundwater; Special topics.
CE723	FINITE ELEMENT METHODS FOR CIVIL ENGINEERING APPLICATIONS		1. Problem formulation, numerical and closed form solutions, weak form, collocation, least square, Galerkin technique, derivation of finite element equations, stiffness matrices, global assembly, coordinate transformation, enforcing boundary conditions, solution of the systems of equations. Convergence, Stability and possible sources of errors; 2. Formulation of one-dimensional truss and beam elements. Application to 2D trusses and frames; 3. Formulation of 2D problems involving plane stress, plane strain, and axis symmetry. Applications to pressure vessels, chimneys, dams, embankments, and pavements; 4. Formulation of plate bending elements. Bending of plate, Von Karman nonlinear plate theory and formulation; 5. Formulation of thin shell elements. Applications to dome, water tank etc; 6. Formulation of threedimensional brick elements. Applications to stress analysis in dam, earthen embankment, tunnel, etc; 7. Nonlinear static and dynamic problems; geometric and material nonlinearity, Pdelta effects in tall buildings, elastoplastic analysis as encountered in structures and geotechnical mechanics,

			seismic soil foundation structure interaction problems; 8. Formulation for contact elements, infinite elements and crack tip elements; 9. CE applications such as 3D elastic problems, consolidation, seepage, transpott and propagation through heterogeneous media; 10. Finite element formulation of fluid flow and transport problems. Applications to pipe, openchannel flow, contaminant and species transport with emphasis to hydraulics and environmental flow modeling.
CE723N	FINITE ELEMENT METHODS FOR CIVIL ENGINEERING APPLICATIONS		1. Problem formulation, numerical and closed form solutions, weak form, collocation, least square, Galerkin technique, derivation of finite element equations, stiffness matrices, global assembly, coordinate transformation, enforcing boundary conditions, solution of the systems of equations. Convergence, Stability and possible sources of errors; 2. Formulation of one-dimensional truss and beam elements. Application to 2D trusses and frames; 3. Formulation of 2D problems involving plane stress, plane strain, and axis symmetry. Applications to pressure vessels, chimneys, dams, embankments, and pavements; 4. Formulation of plate bending elements. Bending of plate, Von Karman nonlinear plate theory and formulation; 5. Formulation of thin shell elements. Applications to dome, water tank etc; 6. Formulation of three-dimensional brick elements. Applications to stress analysis in dam, earthen embankment, tunnel, etc; 7. Nonlinear static and dynamic problems; geometric and material nonlinearity, Pdelta effectsin tall buildings, elastoplastic analysis as encountered in structures and geotechnical mechanics, seismic soil foundation structure interaction problems; 8. Formulation for contact elements, infinite elements and crack tip elements; 9. CE applications such as 3D elastic problems, consolidation, seepage, transpott and propagation through heterogeneous media; 10. Finite element formulation of fluid flow and transport problems. Applications to pipe, openchannel flow, contaminant and species transport with emphasis to hydraulics and environmental flow modeling.
CE731	RISK & RELIABILITY IN GEOTECHNICAL ENGINEERING		Introduction: Sources and types of uncertainties associated with geotechnical analysis,importance of probabilistic methods and reliability based analysis in geotechnical engineering Review of probability and statistics: Discrete and continuous random variables, parameter estimation, testing of hypothesis, regression analysis Fundamentals of reliability analysis: FirstOrder Second Moment (FOSM) method, First Order Reliability Method (FORM), SecondOrder Reliability Method (SORM), Monte Carlosimulation Application towards geotechnical problems: Characterization of uncertainty in field measured and laboratory measured soil properties, uncertainty in interpretation techniques Spatial variability of soil properties, scale of fluctuations, estimation of autocorrelation and auto covariance Probabilistic ground

			water modeling, flow through earth dams Probabilistic slope stability analysis Fundamentals of LRFD design methodology, reliability based design of shallow and deep foundations, settlement analysis Reliability based liquefaction analysis, lateral spreading Development of fragility curves for geotechnical problems. **Course Reference**: 1. Fenton, G. A and Griffiths, D. V. (2008). Risk Assessment in Geotechnical Engineering, Wiley, New York; 2. Phoon, K. K. (Ed.) (2008). Reliability Based Design in Geotechnical Engineering: Computations and Applications, CRC Press; 3. Griffiths, D. V. and Fenton, G. A. (Eds.) (2007) Probabilistic Methods in Geotechnical Engineering, SpringerWienNewYork; 4. Baecher, G. and Christian, J. (2003). Reliability and Statistics in Geotechnical Engineering, Wiley, New York.
CE731A	RISK & RELIABILITY IN GEOTECHNICAL ENGINEERING		Introduction: Sources and types of uncertainties associated with geotechnical analysis, importance of probabilistic methods and reliability based analysis in geotechnical engineering Review of probability and statistics: Discrete and continuous random variables, parameter estimation, testing of hypothesis, regression analysis Fundamentals of reliability analysis: FirstOrder Second Moment (FOSM) method, First Order Reliability Method (FORM), SecondOrder Reliability Method (SORM), Monte Carlo simulation Application towards geotechnical problems: Characterization of uncertainty in field measured and laboratory measured soil properties, uncertainty in interpretation techniques Spatial variability of soil properties, scale of fluctuations, estimation of autocorrelation and autocovariance Probabilistic groundwater modeling, flow through earth dams Probabilistic slope stability analysis Fundamentals of LRFD design methodology, reliability based design of shallow anddeep foundations, settlement analysis Reliability based liquefaction analysis, lateral spreading Development of fragility curves for geotechnical problems. **Course Reference**: 1. Fenton, G. A and Griffiths, D. V. (2008). Risk Assessment in Geotechnical Engineering, Wiley, New York; 2. Phoon, K. K. (Ed.) (2008). Reliability Based Design in Geotechnical Engineering: Computations and Applications, CRC Press; 3. Griffiths, D. V. and Fenton, G. A. (Eds.) (2007) Probabilistic Methods in Geotechnical Engineering, Springer Wien NewYork; 4. Baecher, G. and Christian, J. (2003). Reliability and Statistics in Geotechnical Engineering, Wiley, New York.
CE733	GEOENVIRONMENTAL DESIGN ASPECTS OF SOLID WASTE MANAGEMENT		Identification, characterization and regulatory requirements for disposal of hazardous, nonhazardous and domestic wastes. Waste Management Recycling, composting, incineration and various disposal methods. Site selection and Geoenvironmental investigations. Natural attenuation process and mechanism of

			attenuation. Design practices of solid wastes. Tailing dams for disposal of flyash, coal, copper, iron and other metal wastes. Single and double lined landfill design, linear material clay, geosynthetics amended soils and other admixtures. Leachate collection and detection system. Landfill construction. Construction quality control and performance monitoring. Application of geosynthetics in waste disposal design.
CE791A	LITERATURE SEARCH AND REVIEW		Basics of literature review: Introduction, identifying appropriate search engines Writing style: Styles of citation and referencing Referencing various types of sources: journal articles, conference proceedings, technical reports, online portals, news paper articles Ethics in writing review reports: Plagiarism, use of figure or data from published report, giving proper credit to authors.
CE792A	SCIENTIFIC WRITING SKILLS		Basics of scientific writing Subjects/Actions, Cohesion, Emphasis, Simplicity; Parts of a Scientific papers Abstract, Introduction, Body, Conclusion, Acknowledgements, Reference; Writing styles: Referencing, Citation, Language Making and Handling Figures and Tables Ethics in writing.
CE793A	SCIENTIFIC PRASENTATION SKILLS		Basics of scientific presentation Visuals: choice of type and size of fonts, color combination, styles, use of sketch and pictures Delivering impressive presentation: Usage of language, clarity, simplicity, speed, explaining Figures and Tables Parts of a Scientific presentation Title, motivation, objectives, body, findings, summary, acknowledgements Ethics in using contents from other sources
CE794A	SCIENTIFIC DATA ANALYSIS, PRESENTATION AND INTERPRETATION		Basics of data: Primary data, secondary data, data sources and reliability Tools for data analysis: Identifying the right tool based on the project requirement (eg. Matlab, R, MSExcel, Access, ArcGIS, etc) Presentation of data: Graphical, tabular, and descriptive, Use of graphing tools in programs including Matlab, R, and MSExcel. Interpretation: Interpretation of results and documenting.
CE799	PHD THESIS		Ph. D. Thesis

CHEMISTRY

CHEMISTRY

BS								Template No. CHM-1
C O U R S E S	SEMESTER							
	1st	2nd	3rd	4th	5th	6th	7th	8th
	MTH101A [11]	MTH102A [11]	CHM201A [09]**	CHM202A [09]	CHM303A [09]	CHM322A [09]	CHM423A [06]	HSS-5 (Level-2) [09]
	PHY101A [03]	PHY103A [11]	ESO/SO-1 [*10]*	CHM222A [09]	CHM305A [06]	CHM342A [09]	HSS-4 (Level-2) [09]	OE-4 [09]
	PHY102A [11]	ESC101A [14]	ESO/SO [*10]*	CHM242A [09]	CHM321A [09]	CHM344A [06]	OE-1 [09]	OE-5 [09]
	LIF101A [06]	CHM101A [03]	HSS-2 (Level-1) [11]	ESC201A [14]	CHM345A [09]	DE-1 [09]	OE-2 [09]	OE-6 [09]
	ENG112A/HSS-1 (Level-1) [11]	CHM102A [08]	TA202A [06]	ESO/SO-3 [*10]*	ESO/SO-4 [*10]*	DE-2 [09]	OE-3 [09]	OE-7 [09]
	PE101A [03]	PE102A [03]	COM200A [05]	TA201A [06]	CHM361A [02]	HSS-3 (Level-2) [09]	UGP-3/DE [09] (CHM491A)	UGP-4 [09] (CHM492A) (Extra Credits)
	TA101A [09]				UGP-1 [04] (CHM391A) (Extra Credits)	UGP-2/DE [09]/ (CHM392A)		
	54	50	51*	57*	45/49*	60	51	45/54

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	101	Credits
Department Elective (DE)	:	36	Credits
Open Elective (OE)	:	63	Credits
*SO/ ESO	:	40	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	**413**	**Credits**

REMARKS:

1) *ESO/SO courses are available in a range from 6 to 14 credits each. CHM students may choose any four courses EXCEPT CSO201A, ensuring a minimum of 8 SO credits and totalling up to a minimum of 40 ESO/SO credits.
2) DE credits may include 18 credits of UGP-2 and UGP-3.
3) UGP-1 and UGP-4 are optional and does not count towards DE/OE credits.
4) Upto 36 OE credits may be waived from the minimum requirements for students opting for either Dual Degree or Double Major programme.
5) **EXCEPTION: CHM201A to be done by Y14 and onward batches. Y11, Y12 and Y13 batches shall do CHM203A. Course title, content and credits are same. Just the course number has been changed.

BS-MS (Category – A) *(from the same department)*				Template No. BS-CHM-2
	UG Pre-Requisites		PG Component	
C O U R S E S	Odd Semester	Even Semester	9th	10th
	CHM503A [06]	CHM402A [09]	CHM611A [09]	MS Project [48]
		CHM443A [06]	CHM621A [09]	
			CHM664A [09]	
			DE PG-1 [09]	
			DE PG-2 [09]	
			DE PG-3 [09]	
	06	15	54	48

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION:

PG Component	:	54	Credits
MS Project component	:	48	Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ DUGC Convener.
2) DE PG-1, 2 and 3 may include any CHM6XX level course EXCEPT CHM609A, CHM629A, and CHM640A.
3) Mandatory UG component must be completed before the 9th semester.
4) Course credits and Thesis credits mentioned under the dual degree template are only for the MS part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
5) Upto 36 OE credits may be used from the BS minimum requirements to fulfil requirements for the BS-MS dual degree programme. These will be waived from the BS programme and counted towards PG requirements.

BS/BT-MS (Category – B) *(from other departments)*			Template No. BS-CHM-3
	Mandatory UG Component	PG Component	
		9th	10th
C O U R S E S	UG CHM DE-1 [09]	MS Project -1 [24]	MS Project -2 [24]
	UG CHM DE-2 [09]	CHM305 A [06]	CHM344 A [06]
	UG CHM DE-3 [09]	CHM423 A [06]	CHM DE-8 [09]
	UG CHM DE-4 [09]	CHM DE-6 [09]	CHM DE-9 [09]
	UG CHM DE-5 [09]	CHM DE-7 [09]	
	45	54	48

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION:

PG Component : 54 Credits
MS Project component : 48 Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ DUGC Convener.
2) All UG DE (from 1 to 5) should be selected from Basket –A.
3) *EXCEPTION: CHM201A to be done by Y13 and onward batches. Y11 and Y12 batch shall do CHM203A. Course title, content and credits are same. Just the course number has been changed.
4) Courses in DE-6 to DE-9 may be any from CHM department core or electives (including any CHM6XX level course EXCEPT CHM609A, CHM620A, and CHM649A), which have not been credited by the student as SO / UG CHM DE during the student's UG program.
5) Course credits and Thesis credits mentioned under the dual degree template are only for the MS part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
6) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the dual degree programme. These will be waived from the parent department's BT/BS programme requirements and counted towards PG requirements.

Basket – A
CHM201A [09]*
CHM202A [09]
CHM222A [09]
CHM242A [09]
CHM303A [09]
CHM321A [09]
CHM345A [09]
CHM322A [09]
CHM342A [09]

DOUBLE MAJOR	Template No. CHM-4
Odd Semester	**Even Semester**
CHM201 A [09]*	CHM222 A [09]
CHM303 A [09]**	CHM242 A [09]
CHM321 A [09]	CHM202 A [09]
CHM345 A [09]	CHM322 A [09]
CHM305 A [06]	CHM342 A [09]
CHM423 A [06]	CHM344 A [06]
48	51

TOTAL MANDATORY CREDITS FOR SECOND MAJOR IN CHEMISTRY: 99 CREDITS

REMARKS:

1. *EXCEPTION: CHM201A to be done by Y13 and onward batches. Y11 and Y12 batch shall do CHM203A. Course title, content and credits are same. Just the course number has been changed.
2. **Pre-requisite for CHM303A is waived for double major students.
3. Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.

MINOR			Template No. CHM-5
Title	PHYSICAL CHEMISTRY*	INORGANIC CHEMISTRY	ORGANIC CHEMISTRY
C O U R S E S	CHM321 A [09]	CHM345 A [09]	CHM201 A [09]**
	CHM322 A [09]	CHM342 A [09]	CHM202 A [09]
	Any TWO from: CHM621 A [09] CHM622 A [09] CHM626 A [09] CHM636 A [09] CHM637 A [09] CHM650 A [09] CHM664 A [09] CHM685 A [09] CHM689 A [09] CHM695 A [09] CHM696 A [09] CHM699 A [09]	Any TWO from: CHM616 A [09] CHM631 A [09] CHM646 A [09] CHM647 A [09] CHM651 A [09] CHM654 A [09] CHM668 A [09] CHM691 A [09]	CHM303 A [09] CHM402 A [09] -
	36	36	36

REMARKS:

1) *CSO202A is a pre-requisite for Minor in Physical Chemistry
2) **EXCEPTION: CHM201A to be done by Y13 and onward batches. Y11 and Y12 batch shall do CHM203A. Course title, content and credits are same. Just the course number has been changed.

DEPARTMENT OF CHM			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
CHM101A	CHEMISTRY LABORATORY	0-0-3-0-3	1.Chemical analysis with relevance to everyday lifeI. Determination of amount of Ca2+ in milk by complexometric titration; 2. Estimation of iodine in common iodized salt by iodometry; 3. Estimation of phosphoric acid in cola drinks by molybdenum bluemethod; 4. Analysis of kidney stone model chemical compounds by permanganometric titratton; 5. Extraction of DNA from green peas or onions and its identification; 6. Extraction of caffeine, an alkaloid from tea leaves; 7. How many pigments are there in the green portion of spinach? A paper chromatography experiment to separate the various pigments including chlorophyll Synthesis of Chemical Compounds. I. Preparation and characterization of aspirin, a common medicine; 2. DielsAlder reaction a versatile organic reaction to form CC bonds: a reaction betweenanthracene and maleic anhydride;3. Preparation and characterization of an inorganic coordination complex compound: [Ni[NH3]6f+ 2cr; 4. Organometallic compounds: bridges between inorganic and organic compounds. Acetylation of F errocene; 5. An environmentrelated synthesis: Preparation of potash alum fromscrap aluminumPhotochemistry: Light as a reagent in chemistry; I. Photochemical reduction of ferric oxalate and its use in blueprinting Experiments on Physical Chemistry ConceptsI. Partition of solutes in mixture of solvents: Acetic acid inwater/nbutanol; 2. Kinetics of reactions: An example using the iodidehydrogen peroxide clock reaction; 3. Determining the pi of amino acids by using potentiometry; 4. Weak and strong acids and bases: conductometry A. J. Elias; A Collection of Interesting General Chemistry Experiments. Universities Press, Hyderabad 2009
CHM101N	CHEMISTRY LAB	0-1-3-0-2	Experiments related to general, organic, physical and inorganic chemistry.
CHM102A	GENERAL CHEMISTRY	2-1-0-0-8	Atomic Structure (4 Lectures). Chemical Bonding (5 Lectures). Molecular Spcctmscopy (5 Lectures). Coordination complexes of transition metal ions (3 Lectures). Organometallic Chemistry (3 Lectures). Molecular Structure of organic Compounds (3 Lectures). Organic Reactions of Industrial Relevance (4 Lectures). Chemistry of New Materials: For example, Fullerenes, nanotubes and graphene (1 Lecture) **Course Reference**: 1. Atkins & Julio de Paula: Physical Chemist1y, 8th Edition, Freeman & Co; 2. Atkins & Shriver: Inorganic Chemistry, 4th Edition (2008); 3. Clayden, Greaves, Warren & Wothers: Organic Chemistry, Oxtbrd Univeisity Press.
CHM201N	CHEMISTRY	3-1-0-1-4	Chemistry, man and matter, Experimental methods of structure determination, System at finite temperature,

			Molecular reaction of Transition Metal ionchemistry, Organometallic chemistry, 18electron rule, simple ligands such as CO, ethylene, triphenyl phosphine etc., Homogeneous catalysis, Green chemistry, Structures of organic molecules. Conformations of ethane, butane, cyclohexaneand monosaccharides such as glucose and fructose. Anomeric effect. E and Zconfigurations (inter conversions between E and Z). Optical activity, R and S(in brief), importance of optical activity in drug synthesis and biological activity, Synthesis of organic molecules, Photochemistry of organic and biomolecules, Chemistry of life processes, Biotechnology and Biomedical applications
CHM202A	BASIC ORGANIC CHEMISTRY -II	3-0-0-0-9	Oxidation: (5) With Cr and Mn compounds; with peracids and other peroxides; with periodic acid, Pb (OAc) 4, Hg (OAc)2 and SeO2. Reduction: (6) Catalytic hydrogenation; metal hydride, dissolving metal and hydrazine-based reductions. CramFelkin Anh model. CC Bond Formation: (10) Acyloin, Aldol, Stobbe, Claisen, Knovenagel and Benzoin condensations, Darzens glycidic estersynthesis; Dieckmann reactions, Wittig reaction, DielsAlder and ene reactions, Reformatsky reaction. Acetoacetic ester and malonic ester synthesis. Acylation reactions. Enamine reactions. Gattermannaldehyde synthesis. Michael and Mannich reactions. Synthesis of Polynuclear Hydrocarbons: Carbohydrate Chemistry: Introduction, Structural elucidation and some typical eactions of mono and dischharides. Heterocyclic Chemistry: Furan, Pyrrole, Thiophene, Pyridine, Indole, quinolines etc. Problems: Based on multistep reactions involving CC bond formation, oxidation and Reduction (to be solved inthe class and supplemented by home assignments). **Course Reference**: 1. Carruthers, W., Coldham, I. Some Modern Methods of Organic Synthesis, 2008; 2. House, H. O., Modern Synthetic Reactions; 3. March, J., Advanced Organic Chemistry, 4th ed, 1999; 4. Clayden, Greeves, Warren, and Wothers, Organic Chemistry, 1st ed, 2001; 5. R. Bruckner, Advanced Organic Chemistry, 2002; 6. R. Bruckner, Organic Mechanisms, 2010; 7. M. B. Smith, Organic Synthesis, 3rd Ed. 2010
CHM203A	BASIC ORGANIC CHEMISTRY -I	3-1-0--4	Nomenclature of Organic molecules: 1. Brief revision, Nomenclature of polycyclic compounds including bridged, spiro and other special structures. Structure and Bonding: 2. Nature of bonding in aliphatic, alicyclic, aromatic and heterocyclic compounds; Aromaticity in benzenoid and nonbenzenoid compounds. Alternant and nonalternant hydrocarbons; Dipole moment; Resonance; Inductive and Field effects, hyperconjugation, Steric inhibition of resonance, structural effects on acidity and basicity. Stereo chemistry: Conformational analysis of acyclic systems (Pitzer strain, A strain, etc.) and cyclohexane systems (brief review as studied in Chm 201). Introduction of terminologies such as erythro, threo, exo, endo, epimers, etc. Conformational analysis of decalins and other polycyclic compounds related to steroids. A brief introduction to asymmetric synthesis; Induction of

			chirality on a prochiral carbon atom; R and S nomenclature in (i) cyclic systems (ii) in compounds with more than one chiral centre and (iii) in biphenyls, allenes and spiro compounds. Optical isomerism in compounds without an asymmetric atom, Racemic modifications. Conformation of acyclic molecules, topicity and prostereoisomerism (topicity of ligands and faces), chemical and biochemical transformations of heterotopic ligands and faces. Conformations of cyclic, fused and bridged ring compounds. Allylic strain (A1,2 and A1,3) and other strains. **Course Reference**: 1. March, J., Advanced Organic Chemistry, 4th ed, 1999; 2. Nasipuri, D., Stereochemistry of Organic Compounds, 2nd ed., 1995; 3. Solomons, T. W. G., Organic Chemistry 6th ed, 1996; 4. Sykes, Peter, A guide book to Mechanism in Organic Chemistry; 5. R. Bruckner, Advanced Organic Chemistry, 2002; 6. R. Bruckner, Organic Mechanisms, 2010; 7. M. B. Smith, Organic Synthesis, 3rd Ed. 2010.
CHM205	INDUSTRIAL ORGANIC CHEMISTRY	3-1-0--4	Various aspects of the energy and raw material supply: Coal, oil, natural gas,nuclear, and biomass as energy sources; Basic products of industrial synthesis: synthesis gas, methanol, formaldehyde, halogen derivatives of methane,chlorofluoro hydrocarbons; Olefins:Historical perspective, cracking of hydrocarbons,ethylene, butanes, higher olefins, unbranched higher olefins and their use inmetathesis reactions, Acetylene: Significance and manufacturing process for acetylene, manufacture through calcium carbide, thermal process, applications of acetylene, 1,3Dioolefins:1,3Butadiene, industrial manufacture from cracking, dehydrogenation, applications of butadiene, Synthesis using carbon monoxide: Hydroformylation, industrial operations,utilization of oxo products, carbonylation of olefins; Oxidation products of ethylene: Ethylene oxide, process operation, ethyleneglycol, ethylene glycol ethers, acetaldehyde, acetic acid, acetic anhydride, Alcohols: Ethanol, propanol, butanols, amyl alcohols, aldol synthesis, polyhydric alcohols, neopentyl glycol. Vinylhalogen and oxygen compounds: Vinyl chloride, vinylidene chloridevinyl acetate, binyl ethers; Polyamides: Adipic acid, hexamethylenediamine, adiponitrile, lactams; Propene conversion products; Propylene oxide, acetone, acrolein, allylchloride, acrylonitrile.; Aromatics: Source of feedstocks, coking of hard coal, isolation, special separation techniques, condensed aromatics, naphthalene, anthracene, hydrodealkylation. Benzene derivatives; Styrene, cumene, cyclohexane, phenol, maleic anhydride, nitrobenzene, aniline, diisocyanates. Oxidation products of xylene and naphthalene; Phthalic anhydride, esters of phthalic acid and derivatives, terephthalic acid.
CHM222	BASIC PHYSICAL CHEMISTRY	3-1-0-0-4	1. Zeroth Law of Thermodynamics: Equilibrium, State Functions, Temperature, Equations of State; 2. First Law of Thermodynamics: Work, Heat, Internal Energy, Heat Capacity, Concept of Enthalpy; 3. Second Law of Thermodynamics: Reversible and Irreversible Process, Heat

			Engines,Carnot Cycle, Different statements of the Second Law, Spontaneous Change, Entropy; 4. Third Law of Thermodynamics: Concept of the absolute zero temperature; 5. Free Energy and Standard States: Free energies and Thermodynamic potentials, LegendreTransforms, Equilibrium and NonEquilibrium, Chemical Potentials, Free Energy, Standard States, Reaction Thermodynamics, Equilibrium Constant; 6. Equilibrium Thermodynamics: Chemical Potential of Mixtures, Phase Equilibrium, PhaseRule, Clapeyron Equation, Phase Diagram; 7. Real Gases: Equations of State, Phase Transitions; 8. Solutions: Molarity, Partial Molar Quantities, Mixing, Ideal Solutions, NonIdeal Solutions, Electrolytes, Ionic activity and the DebyeHueckel Theory, the Nernst Equation, Colligative properties, Multicomponent phase diagrams9. Kinetic Theory of Gases and Transport Processes10. Reaction Kinetics: Reaction Rates, Rate Laws, Reaction Mechanisms, Applications **Course Reference**: 1. P. W. Atkins and Julio de Paula, Physical Chemistry; 2. I. N. Levine, Physical Chemistry; 3. R. J. Silbey, R. A. Alberty, and M. G. Bawendi, Physical Chemistry
CHM222A	BASIC PHYSICAL CHEMISTRY	3-0-0-0-9	1. Zeroth Law of Thermodynamics: Equilibrium, State Functions, Temperature, Equations of State; 2. First Law of Thermodynamics: Work, Heat, Internal Energy, Heat Capacity, Concept ofEnthalpy; 3. Second Law of Thermodynamics: Reversible and Irreversible Process, Heat Engines,Carnot Cycle, Different statements of the Second Law, Spontaneous Change, Entropy; 4. Third Law of Thermodynamics: Concept of the absolute zero temperature; 5. Free Energy and Standard States: Free energies and Thermodynamic potentials, LegendreTransforms, Equilibrium and NonEquilibrium, Chemical Potentials, Free Energy, Standard States, Reaction Thermodynamics, Equilibrium Constant; 6. Equilibrium Thermodynamics: Chemical Potential of Mixtures, Phase Equilibrium, Phase Rule, Clapeyron Equation, Phase Diagram; 7. Real Gases: Equations of State, Phase Transitions; 8. Solutions: Molarity, Partial Molar Quantities, Mixing, Ideal Solutions, NonIdeal Solutions,Electrolytes, Ionic activity and the DebyeHueckel Theory, the Nernst Equation, Colligative properties, Multicomponent phase diagrams; 9. Kinetic Theory of Gases and Transport Processes; 10. Reaction Kinetics: Reaction Rates, Rate Laws, Reaction Mechanisms, Applications. **Course Reference**: 1. P. W. Atkins and Julio de Paula, Physical Chemistry; 2. I. N. Levine, Physical Chemistry; 3. R. J. Silbey, R. A. Alberty, and M. G. Bawendi, Physical Chemistry.
CHM242A	BASIC INORGANIC CHEMISTRY	3-0-0-0-9	Basic Concepts: 1. Molecular symmetry, point groups and character tables; 2. Bonding models; 3. Chemical forces; 4. Acids and Bases MainGroup Chemistry; 5. Chemistry of selective maingroup elements and their compoundsTransition Metal Chemistry; 6. Types of ligands, Structure and isomerism of transition metal complexes, Bonding intransition metal complexes Valence Bond, Crystal Field and Molecular

			Orbital theories,effects of dorbital splitting; 7. Organometallic compounds: EAN rule, metalcarbonyls, metalolefins, reactions of organometallic compounds; 8. Homogeneous and Heterogeneous Catalysis Lanthanide Chemistry; 9. Chemistry of fblock elements: special features, lanthanide contraction, coordinationnumber, structure and reactions. **Course Reference**: 1. Shriver, D. F.; Atkins, P. W. and Langford, C. G. Inorganic Chemistry, 3rd Edn., Oxford University, Oxford, 1999; 2. Jolly, W. L.: Modern Inorganic Chemistry, 2nd Edn., 1991; 3. Cotton, F. A. Chemical Applications of Group Theory, 3rd Edn., John Wiley and Sons,2003; 4. Cotton, F. A.; Wilkinson, G., Basic Inorganic Chemistry, 3rd Edn., John Wiley and Sons 1998; 5. Cotton, F.A.; Carlos, A. M,; and Bochmann, M. Advanced Inorganic Chemistry, 6th Edn .Wiley Interscience Publication, 2001.
CHM301	BASIC ORGANIC CHEMISTRY-I	3-1-0-0-4	Nomenclature of organic molecules Structure and bonding, Stereochemistry, Reactive Intermediates, Substitution and Elimination Reactions, Molecular Rearrangements, Photochemistry.
CHM302	BASIC ORGANIC CHEMISTRY II	3-1-0-0-4	Oxidation, Reduction, CC Bond Formations, Syhthesis of Polynuclear Hydrocarbons, Carbohydrates, Nucleotides, Amino Acids and Peptides.
CHM303A	ORGANIC CHEMISTRY I	3-0-0-0-9	Stereochemistry, Dynamic stereochemistry: Conformation and Reactivity. Various chemo, regio and stereo selective reactions. Reactive Intermediates: Carbenes and carbenoids Radicals: Structure, reactivity, selectivity and mechanisms of radicals and radical based reactions, involving various functional groups. Radical cations and radical anions. Carbocations: Nonclassical carbocation. Sigma and piparticipation. Mechanistic and Stereochemical Aspects of : Baeyer Villiger, Claisen (including JohnsonClaisen, IrelandClaisen, Eschenomser, Overman modifications) Cope, and oxyCope, Wittig rearrangements (both 1,2 and 2,3 Wittig rearrangements);ene and metalloene reactions; (2+2), (3+2) and (4+2) cycloadditions; Barton reaction.Organometallic Chemistry : (5)Mechanism and stereochemistry of various reactions. Palladium based reactions such as Heck, Stille, Suzuki, Sonogashira, Buchwald Hartwig couplings; TsujiTrost CC bond formations; Ni and Sncatlysed reactions. Enzymatic Reactions: (3) Mecahnistic and stereochemical aspects of hydrolases (including esterases and lipases), oxidoreductases. Green-Chemistry: Concepts and applications (3)Classification and Structures o f some natura l products such as terpenoids, steroids, alkaloids andprostaglandins (5) **Course Reference**: 1. March, J., Advanced Organic Chemistry, 4th ed, 1999; 2. Nasipuri, D., Stereochemistry of Organic Compounds, 2nd ed., 1995; 3. Solomons, T. W. G., Organic Chemistry 6th ed, 1996; 4. Sykes, Peter, A guide book to Mechanism in Organic Chemistry; 5. R. Bruckner, Advanced Organic Chemistry, 2002; 6. R. Bruckner, Organic Mechanisms, 2010; 7. M. B. Smith, Organic Synthesis, 3rd Ed. 2010; 8. Clayden, Greeves, Warren, and Wothers, Organic Chemistry, 1st ed, 2001

CHM305A	ORGANIC QUALITATIVE & QUANTITATIVE ANALYSIS	0-0-6-0-6	1. Experimental Techniques (A) Purification of Organic Compoundsa. Recrystallisationb. Sublimation at atmospheric pressure and under reduced pressurec. Separation or organic compounds by Steam distillationd. Distillation of organic compounds under reduced pressuree. Bulbtobulb distillation under reduced pressure (B) Chromatographya. Thin layer chromatography (TLC) and calculation of Rf values, b. Column Chromatography: separation of organic mixture.c. Preparative TLC: preparation of plates and separation of organic mixtures (C) Physical Constantsa. Melting Points and Boiling Pointsb. Optical rotation and calculation of specific rotation and molecular rotation (D) Spectroscopic Methodsa. Preparation of an ester and its confirmation by IR and NMRb. Structure illucidation of unknown compounds based on the given spectral data 2. Investigation and Characterization of Organic Compoundsa. Detection of elements present in a given organic compound.b. Identification of functional groups in a given organic compound.c. Identification of unknown organic compounds.d. Separation of organic mixture by chemical methods, preparation of derivatives, and identification of the material.
CHM321A	PHYSICAL CHEMISTRY I	3-0-0-0-9	1. Introduction: importance, historic background, quantum mechanics vs classical mechanics, waveparticle duality, uncertainty principle; 2. Schroedinger equation: wavefunction and interpretation, time dependent and time independent Schroedinger equation, eigenvalue problem; 3. Quantum mechanics of some simple systems: free particle, particle in a box , harmonicoscillator, one dimensional potential step and barrier; 4. Angular Momentum: rigid rotor, orbital and spin angular momentum; 5. Hydrogen and hydrogen like atoms; 6. Approximate methods: perturbation theory, variational method, some simple examples; 7. Many electron atom: Pauli antisymmetry principle, Slater determinant, He atom, Li atom. **Course Reference**: 1. I. N. Levine, Quantum Chemistry; 2. J. P. Lowe and K. A. Peterson, Quantum Chemistry; 3. D. A. McQuarrie, Quantum Chemistry; 4. D. A. McQuarrie, J. D. Simon, Physical Chemistry: A molecular approach; 5. P. W. Atkins, Molecular Quantum Mechanics
CHM322A	PHYSICAL CHEMISTRY -II	3-0-0-0-9	Equilibrium Thermodynamics: Laws of thermodynamics, the equilibrium state, thermodynamic variables, conjugate quantities, thermodynamic potentials Statistical Mechanics: Kinetic Theory of gases, Boltzmann distribution,the ensemble postulate, partition function, canonical ensemble, other ensembles, fluctuations, ideal monatomic, diatomic and polyatomic gases, chemical equilibrium, quantum statistics, Transport Phenomena: Transport coefficients, thermal conductivity, diffusivity, viscosity, ionic conductivity, Limiting law of DebyeHckelOnsager, Nernst Einstein relation, Stokes Einstein relation Molecular Reaction Dynamics: Collision theory, activation energy,transitionstate theory, reactions as trajectories, molecular beam experiments,reactions in liquid phase, Kramers theory, Diffusion limited reactions **Course Reference**: 1. P.W. Atkins and Julio de Paula:

			Physical Chemistry; 2. I.N. Levine: Physical Chemistry; 3. D.A. McQuarrie and J. D. Simon: Physical Chemistry A Molecular Approach; 4. D. A. McQuarrie, Statistical Mechanics; 5. H. B. Callen: Thermodynamics and an introduction to Thermostatistics; 6. David Chandler: Introduction to Modern Statistical Mechanics; 7. R.S. Berry, S.A. Rice and John Ross: Physical Chemistry
CHM341	BASIC INORGANIC CHEMISTRY	3-0-0-0-4	Vector model of the atom (RussellSaunders Coupling), the molecule and molecularions, periodicity of the elements, shielding, the size of the atoms, ionizationenergy, electron affinity, inorganic solid state, Covalent bonding, Heteronuclear bonds, Types of chemical forces, Effects of chemical forces, Hard and soft acidsand bases: Classification, acids and bases, Optical activity, Experimental evidence for metalligand orbital overlap.
CHM342A	INORGANIC CHEMISTRY -II	3-0-0-0-9	1. Symmetry, point groups, character tables, concepts of orbital symmetries for dorbital splitting diagrams in different stereochemistry; 2. Synthesis and structure of mononuclear and multinuclear transition metal complexes; 3. Theories of bonding. Crystalfield and Molecular orbital, effects of ligandfield (spectrochemical series, consequences of dorbital splitting); 4. Spectroscopy of transitionmetal complexes: Russell Saunders coupling scheme, Term Symbols; 5. Magnetism of transitionmetal complexes: Curie law, para, ferro, antiferro and ferromagnetic systems; 6. Reaction mechanism of transition metal complexes and electrontransfer reactions; 7. Introduction of bioinorganic chemistry: heme, nonheme, FeS proteins; 8. New trends of research: supramolecular chemistry, metalorganic frameworks, gasstorage,nanochemistry, the renaissance of carbon; 9. Transition metalbased inorganic materials (magnetic, optical and biomaterials) **Course Reference**: 1. Huheey, J. E.; Keiter, K. E.; Keiter, R. L., Inorganic Chemistry Principles of Structure and Reactivity: 4th Edn, Pearson Education, 2008; 2. Shriver. D. F.; Atkins. P. W.; Langford, C. G., Inorganic Chemistry. 3rd Edn., OxfordUniversity, Oxford, 1999; 3. Cotton, F. A.; Murillo, C. A.; and Bochmann, M., Advanced Inorganic Chemistry 6th Edn. ,Wiley Interscience, 2001; 4. Cotton, F. A., Chemical Applications of Group Theory 3rd ed., John Wiley and Sons, 2003; 5. Carter, R. L., Molecular Symmetry and Group Theory, John Wiley and Sons, 3rdEdn.,1998; 6. Kahn, O., Molecular Magnetism, VCH, Weinheim, 1993; 7. Lehn, J. M., Supramolecular Chemistry: Concepts and Perspectives, VCH, Weinheim,1995; 8. Berg, J. M.; Lippard, S. J., Principles of Bioinorganic Chemistry, University Science Books,CA, 1995.
CHM344A	INORGANIC CHEMISTRY LABORATORY EXPERIMENTS	0-0-6-0-6	Estimation of iron in minute quantities by UVvis spectrophotometry Principles of colorimetric analysis: determination of iron content of an unknown sample.Preparation of hexamine nickel (II) chloride: estimation of ammonia and nickel bytitrimetric and gravimetric methods Determination of complex composition using simple techniques Preparation of diamagnetic and

			paramagnetic maingroup and transition metalacetylacetonates Synthesis, isolation and spectroscopic characterization of the complexes Synthesis and characterization of ferrocene and acetyl ferrocene Synthesis of the complex and their purification using chromatography Acidbase and redox titration of tablets containing Vitamin C Estimation of ascorbic acid in Vitamin C tablets Paper chromatographic separation of Cu2+, Fe3+ and Ni2+Utilization of paper chromatographic techniques to separate the metal salts Spectrophotometric determination of phosphate: estimation of phosphate in coladrinks Determination of concentration of phosphates applying Beer Lambert law 8. Potassium trisoxalatoferrate (III): synthesis, analysis and photochemistry Synthesis of the complex and its utilization in blueprinting experiment Elias, A. J., A Collection of Interesting General Chemistry Experiments, Universities Press (India) Pvt. Ltd., 2002.Roesky, H. W.; Mckel, K., Chemical Curiosities: spectacular experiments and inspired quotes, VCH, 1996. Handouts prepared for the laboratory experiments: collections from various literature sources
CHM345A	INORGANIC CHEMISTRY I	3-0-0-0-9	To be Procured1. Representative Chemistry of MainGroup Elements (15) (a) Organometallic Chemistry of Lithium and Magnesium: synthesis, structure and reactivity (b) Chemistry of Boron: boranes, bonding in boranes, topology of boranes, synthesis andreactivity, carboranes and metallacarboranes. New Lewis acids based on boron; polymersupported Lewis acids (c) Chemistry of Aluminum: Aluminum alkyls, use of aluminum alkyls in polymerization ofolefins (d) C60 and carbon nanotubes: discovery, preparation and selected reactions (e) Chemistry of Silicon: organosilicon compounds, silicates and aluminosilicates; 2. Unusual Compounds of MainGroup Elements (10) (a) Multiple bonding in heavier maingroup elements, unusual compounds of maingroupelements: (i) SiSi double bond, SiSi triple bond, PP double bond, BiBi double bond,synthesis, structure and reactivity(b) Chemistry of lowvalent compounds: Synthesis, structure and bonding models andreactivity of Al(I), Si(II) lowvalent compounds(c) Chemistry of stable Nheterocyclic carbenes, use of carbenes in catalysis(d) Inorganic rings and polymers: cyclo and heterocyclophosphazenes, polysilanes, borazine and boron nitride 3. Chemistry of halogens and noble gases: recent trends, CFCs and ozone layer (2) 4. Organometallic Chemistry (15)(a) bonded systems: metalalkyls, aryls and hydrides, stability, preparation and reactivity, metalcarbonyls, metalphosphines, metalnitrosyls, metalisocyanides: structures, reactivity and bonding Metalcarbenes, metalcarbynes, Fischer carbenes, Schrock carbenes, complexes with Nheterocyclic carbenes, olefin metathesis(b) bonded systems: metalolefins, alkyls, alkynes, dienes, Cp and Cp*, structure,bonding and reactivity(c) Applications of organometallics in organic synthesis: CC bond coupling reactions (Heck, Sonogashira, Suzuki), reduction using transition metal hydrides, asymmetric hydrogenation.

			Course Reference: 1. Elschenbroich, C.; and Salzer, A., Organometallics: A Concise Introduction, 3rd Edn. 1999; 2. Greenwood, N. N.; Earnshaw, A., Chemistry of the Elements, Pergamon Press, 2nd Edn.,2002; 3. Douglas, B.; McDaniel, D.; and Alexander, J., Concepts and Models of InorganicChemsitry. 3rd Edn., John Wiley, New York. 1993; 4. Crabtree, R. H. The Organometallic Chemistry of the Transition Metals, 5th Edn., JohnWiley and Sons, 2009
CHM391A	UNDER GRADUATE PROJECT-I	0-0-4-0-4	5TH SEMESTER UNDERGRADUATE PROJECT(Content?)
CHM392A	UG PROJECT II	0-0-0-0-9	UG PROJECT II (Content?)
CHM399A	CHEMISTRY COMMUNICATION SKILLS	0-0-0-2-2	CHEMISTRY COMMUNICATION SKILLS (Content?)
CHM401	ORGANIC CHEMISTRY I	3-0-0-0-4	Stereochemistry, Dynamic stereochemistry, Mechanistic and Stereochemical aspects, Reactive Intermediates: Carbenes, Nitrenes, Radicals, Carbocations.
CHM401A	ORGANIC CHEMISTRY I	3-0-0-0-9	Stereochemistry, Dynamic stereochemistry, Mechanistic and Stereochemical aspects, Reactive Intermediates: Carbenes, Nitrenes, Radicals, Carbocations. 21-JUL-2014
CHM402	ORGANIC CHEMISTRY II	3-0-0-0-4	Oxidation: (6) Oxidation involving organosulfur (such as Swern) and organoselenium compounds; DessMartin, IBXand related hypervalent iodine based oxidations, Ag2CO3/celite Prevost, photosensitised oxidation, dimethyldioxirane, RuO4, 2sulfonyl oxaziridne, transition metal catalysed oxidation, oxidation atunfunctionalised carbons, Fleming Tamao oxidation, and microbial oxidations.Reduction: (6)Using silanes, Al and B based reagents (e.g. DIBAL, Lselectride, Kselectride, RedAl etc.), low valentTi species, microbial reductions (NADH model etc.) Asymmetric Synthesis: (8) Sharpless epoxidation and dihydroxylation, Jacobsens epoxidation, Coreys oxazaborolidinecatalyzed reduction, Noyoris BINAP reduction, SAMP, RAMP, Evans oxazoline and Oppolzer sultams, Aldol reaction (in brief: only principles using models).CC Bond Formation: (14) via anions to electron withdrawing groups (carbonyl group, esters, NO2, SO2Ph, CN etc.) via B and Si enolates via imines Michael additions (cuprates etc.) Via allyl boron, allyl tin, allyl and vinyl silanes Metal catalyzed Cyclopropanation reactions (including Simmons Smith reaction) Ringclosing, ringopening and cross metathesisOrganic Synthesis: (8) Application of above reactions and the ones studied in CHM 401 in synthesis of natural products. **Course Reference**: 1. Carruthers, W., Coldham, I. Some Modern Methods of Organic Synthesis, 2008; 2. Smith, M. B., Organic Synthesis, 2nd ed., 2002; 3. Carreira, E. M.; Kvaerno, L. Classics in stereoselective synthesis, 2009; 4. Nicolaou, K. C.; Sorenson, E. J., Classics in total synthesis, 1996; 5. Nicolaou, K. C.; Snyder, S. A., Classics in total synthesis II, 2003; 6. Tsuji, J., Transition metal reagents and catalysts, 2000.

CHM402A	ORGANIC CHEMISTRY II	3-0-0-0-9	Oxidation: (6) Oxidation involving organo sulfur (such as Swern) and organoselenium compounds; Dess Martin, IBXand related hypervalent iodine based oxidations, Ag2CO3/celite Prevost, photosensitised oxidation, dimethyl dioxirane, RuO4, 2sulfonyl oxaziridne, transition metal catalysed oxidation, oxidation at unfunctionalised carbons, Fleming Tamao oxidation, and microbial oxidations.Reduction: (6) Using silanes, Al and B based reagents (e.g. DIBAL, Lselectride, Kselectride, RedAl etc.), low valentTi species, microbial reductions (NADH model etc.) Asymmetric Synthesis: (8) Sharpless epoxidation and dihydroxylation, Jacobsens epoxidation, Coreys oxazaborolidine catalyzed reduction, Noyoris BINAP reduction, SAMP, RAMP, Evans oxazoline and Oppolzer sultams, Aldol reaction (in brief: only principles using models).CC Bond Formation: (14) via anions to electron withdrawing groups (carbonyl group, esters, NO2, SO2Ph, CN etc.) via B and Si enolates via imines Michael additions (cuprates etc.) Via allyl boron, allyl tin, allyl and vinyl silanes Metal catalyzed Cyclopropanation reactions (including Simmons Smith reaction) Ringclosing, ringopening and cross metathesisOrganic Synthesis: (8) Application of above reactions and the ones studied in CHM 401 in synthesis of natural products. **Course Reference**: 1. Carruthers, W., Coldham, I. Some Modern Methods of Organic Synthesis, 2008; 2. Smith, M. B., Organic Synthesis, 2nd ed., 2002; 3. Carreira, E. M.; Kvaerno, L. Classics in stereoselective synthesis, 2009; 4. Nicolaou, K. C.; Sorenson, E. J., Classics in total synthesis, 1996; 5. Nicolaou, K. C.; Snyder, S. A., Classics in total synthesis II, 2003; 6. Tsuji, J., Transition metal reagents and catalysts, 2000
CHM421	PHYSICAL CHEMISTRY I	3-0-0-0-4	Atomic Structure, chemical binding and molecular structure. Elements ofmolecular spectroscopy.
CHM421A	PHYSICAL CHEMISTRY I	3-0-0-0-9	Atomic Structure, chemical binding and molecular structure. Elements ofmolecular spectroscopy. 21-JUL-2014
CHM422	PHYSICAL CHEMISTRY II	3-0-0-0-4	Thermodynamics, Statistical Thermodynamics, Chemical kinetics.
CHM423	PHYSICAL CHEMISTRY LAB	0-0-6-0-2	1. Calibration of volumetric apparatus. (One day); 2. Analysis of the rotationalvibrational spectra of HCl molecules. (One day; 3. Determination of partial molal volume. (One day); 4. Determination of the isotherm for a three omponent system. (Two days); 5. Kinetics of fast reactions by stoppedflow technique. (One day); 6. Spectrophotometric determination of the acid dissociation constant (Two day); 7. The measurement of electrical conductance for the determination of the equivalentconductance at infinite dilution (Two days); 8. Rate of the hydrolysis of sucrose using polarimeter. (Two day); 9. Determination of pKa of polybasic acid with the pH meter. (One day); 10. Determination of critical miceller concentration. (One day); 11. Determination of transport number by moving boundary method. (One day); 12. Polarizability from refractive index measurements. (One day);

			13. Formula and stability constant of a complex by spectrophotometry. (One day); 14. Fluorescence quantum yield determination of an unknown molecule. (One day); 15. Fluorescence spectrum and sternvolmer quenching constant. (One day); 16. IR and Raman spectroscopy of solvent mixtures. (Two days); 17. Computing Potential Energy Surface of molecules using Quantum Mechanics. (Twodays) **Course Reference**: 1. Experimental physical chemistry, F. A. Bettelheim; 2. Experimental physical chemistry, G. P. Matthews; 3. Experimental physical chemistry, F. Daniels; 4. Experimental physical chemistry, A. Halpern and G. McBane; 5. Experimental Physical Chemistry, D. P. Shoemaker, C. W. Garland, and J. W. Nibler
CHM423A	PHYSICAL CHEMISTRY LABORATORY	0-0-6-0-6	1. Calibration of volumetric apparatus. (One day); 2. Analysis of the rotationalvibrational spectra of HCl molecules. (One day); 3. Determination of partial molal volume. (One day); 4. Determination of the isotherm for a three-component system. (Two days); 5. Kinetics of fast reactions by stoppedflow technique. (One day); 6. Spectrophotometric determination of the acid dissociation constant (Two day); 7. The measurement of electrical conductance for the determination of the equivalentconductance at infinite dilution (Two days) 8. Rate of the hydrolysis of sucrose using polarimeter. (Two day); 9. Determination of pKa of polybasic acid with the pH meter. (One day); 10. Determination of critical miceller concentration. (One day); 11. Determination of transport number by moving boundary method. (One day); 12. Polarizability from refractive index measurements. (One day); 13. Formula and stability constant of a complex by spectrophotometry. (One day); 14. Fluorescence quantum yield determination of an unknown molecule. (One day); 15. Fluorescence spectrum and sternvolmer quenching constant. (One day); 16. IR and Raman spectroscopy of solvent mixtures. (Two days); 17. Computing Potential Energy Surface of molecules using Quantum Mechanics. (Twodays) **Course Reference**: 1. Experimental physical chemistry, F. A. Bettelheim; 2. Experimental physical chemistry, G. P. Matthews; 3. Experimental physical chemistry, F. Daniels; 4. Experimental physical chemistry, A. Halpern and G. McBane; 5. Experimental Physical Chemistry, D. P. Shoemaker, C. W. Garland, and J. W. Nibler
CHM441	INORGANIC CHEMISTRY I	3-0-0-0-4	Principles of modern inorganic chemistry, discussion of the chemistry of nontransitionelements.
CHM441A	INORGANIC CHEMISTRY I	3-0-0-0-9	Principles of modern inorganic chemistry, discussion of the chemistry of nontransition elements.
CHM442	INORGANIC CHEMSTRY II	3-0-0-0-4	Coordination Chemistry: Bonding, Spectra, Magnetism, Structure and Reaction Mechanism, Supramolecular Chemistry, Molecular Magnetism, Organometallic Chemistry, Inorganic Chemistry of Biological systems.
CHM481	BIOSYSTEMS	3-0-0-0-4	Buffers (their use in study of biomolecules), pH, pKa of amino acids, D and L amino acidnomenclature. (1) Proteins: protein sequencing by chemical and mass & NMR spectroscopic methods), Use of spectroscopic tools in studying

			biomolecules. Primary (single letter amino acid codes), Ramachandran plot, secondary, 310, helices, parallel and antiparallel sheets, turns, turns), circular dichroism of secondary structures, tertiary (motifs and domains: someimportant motifs like Rossman fold, helix turn helix, 4 helix bundles, beta barrel) andquaternary structure (Hemoglobin and Myoglobin). Protein Engineering (17). Nucleic acids: A, B and ZDNA structures, Method of replication, sequencing of nucleic acids (chemical, dideoxy and fluorescence), Transcription, Translation, genetic code, genomes, genes, over expression of recombinant proteins, mutagenesis (random and site directed) Polymerase chain reaction (PCR). Use of modified bases in PCR (9) Carbohydrates and Glycoproteins, proteoglycans, Membranes and lipids, bacteial cell wallsynthesis and mechanism of some important antibiotics like penicllin, antibiotic resistance. (4) Metabolism: Photosynthesis, Calvins cycle, Glycolysis, Krebs cycle, electron transport, cofactors. (4) Enzymes and their kinetics: Michaelis Menten kinetics, Reaction order, competitive, uncompetitive, noncompetitive and irreversible inhibition of enzymes. Effect of pH, temperatureon enzyme activity. (4) Biophysical techniques to purify and study proteins. Dialysis, salting out and precipitation byorganic solvents, Ion exchange, gel filtration, reversed phase, affinity chromatography, ultracentrifugation, gel electrophoresis. **Course Reference**: 1. Fundamentals of Biochemistry by Voet, Voet and Pratt; 2. Biochemistry by L. Stryer; 3. Proteins by T.E. Creighton; 4. Genes VII by B. Lewin, Introduction to protein structure by Branden and Tooze; 5. Enzyme structure and Mechanism by Alan Fersht
CHM481A	BIOSYSTEMS	3-0-0-0-9	Buffers (their use in study of biomolecules), pH, pKa of amino acids, D and L amino acid nomenclature. (1 Proteins: protein sequencing by chemical and mass & NMR spectroscopic methods), Use of spectroscopic tools in studying biomolecules. Primary (single letter amino acid codes), Ramachandran plot, secondary, 310, helices, parallel and antiparallel sheets, turns, turns, circular dichroism of secondary structures, tertiary (motifs and domains: some important motifs like Rossman fold, helix turn helix, 4 helix bundles, beta barrel) and quaternary structure (Hemoglobin and Myoglobin). Protein Engineering (17). Nucleic acids: A, B and ZDNA structures, Method of replication, sequencing of nucleic acids (chemical, dideoxy and fluorescence), Transcription, Translation, genetic code, genomesgenes, over expression of recombinant proteins, mutagenesis (random and site directed). Polymerase chain reaction (PCR). Use of modified bases in PCR (9) Carbohydrates and Glycoproteins, proteoglycans, Membranes and lipids, bacteial cell wallsynthesis and mechanism of some important antibiotics like penicllin, antibiotic resistance. (4) Metabolism: Photosynthesis, Calvins cycle, Glycolysis, Krebs cycle, electron transport, cofactors. (4) Enzymes and their kinetics: MichaelisMenten kinetics, Reaction order, competitive,

			uncompetitive, noncompetitive and irreversible inhibition of enzymes. Effect of pH, temperatureon enzyme activity. (4) Biophysical techniques to purify and study proteins. Dialysis, salting out and precipitation byorganic solvents, Ion exchange, gel filtration, reversed phase, affinity chromatography, ultracentrifugation, gel electrophoresis. **Course Reference**: 1. Fundamentals of Biochemistry by Voet, Voet and Pratt; 2. Biochemistry by L. Stryer, Proteins by T.E. Creighton; 3. Genes VII by B. Lewin; 4. Introduction to protein structure by Branden and Tooze; 5. Enzyme structure and Mechanism by Alan Fersht.
CHM491A	UNDER GRADUATE PROJECT-III	0-0-0-0-9	UG PROJECT (UGPIII)
CHM503	ORGANIC PREPARATION LAB	0-0-6-0-2	Preparations of various organic compounds employing different reactions willbe carried out, with a view to give the student sufficient training in syntheticorganic chemistry.
CHM503A	ORGANIC PREPARATION LAB	0-0-6-0-6	Preparations of various organic compounds employing different reactions willbe carried out, with a view to give the student sufficient training in syntheticorganic chemistry
CHM521	MATHEMATICS FOR CHEMISTRY	3-0-0--4	Preparations of various organic compounds employing different reactions willbe carried out, with a view to give the student sufficient training in syntheticorganic chemistry.
CHM521A	MATHEMATICS FOR CHEMISTRY	3-0-0-0-9	Preparations of various organic compounds employing different reactions willbe carried out, with a view to give the student sufficient training in syntheticorganic chemistry. 21-JUL-2014
CHM600	MATHEMATICS FOR CHEMISTRY	3-0-0--4	Error Analysis, Scalars, vectors, curl, divergence and gradient, ordinary 3000[4] differential equations, symmetry and group theory, matrices, etc.
CHM600A	MATHEMATICS FOR CHEMISTRY	3-0-0-0-9	Error Analysis, Scalars, vectors, curl, divergence and gradient, ordinary 3000[4] differential equations, symmetry and group theory, matrices, etc.
CHM602	ADVANCED ORGANIC CHEMISTRY II	3-0-0-0-4	Principles of retrosynthetic analysis: Linear and convergent synthesis, Synthesis under steric control, Regio and stereoselective synthesis, Basic synthetic methods. Methodolgies for the construction of membered rings, medium and large rings. Application in natural product synthesis. Methodolies for the construction of membered heterocyclic rings. Application In organic synthesis. **Course Reference**: 1. Corey and Cheng, The Logic of Chemical Synthesis, Wiley, 1989; 2. Nicolaou and Sorensen, Classics in Total Synthesis, 1996; 3. Nicolaou and Snyder, Classics in Total Synthesis II, 2003; 4 Carey and Sundberg, Advanced Organic Chemistry, Part I and II, 4th ed., 2000.
CHM602A	ADVANCED ORGANIC CHEMISTRY II	3-0-0-0-9	Principles of retrosynthetic analysis: Linear and convergent synthesis, Synthesis under steric control, Regio and stereoselective synthesis, Basic synthetic methods. Methodolgiges for the construction of membered rings, medium and large rings. Application in natural product synthesis. Methodolies for the construction of membered heterocyclic rings. Application In organic synthesis. **Course Reference**: 1. Corey and Cheng, The Logic of

			Chemical Synthesis, Wiley, 1989; 2. Nicolaou and Sorensen, Classics in Total Synthesis, 1996; 3. Nicolaou and Snyder, Classics in Total Synthesis II, 2003; 4. Carey and Sundberg, Advanced Organic Chemistry, Part I and II, 4th ed., 2000.
CHM609	PRINCIPLES OF ORGANIC CHEMISTRY	3-0-0-0-4	Stereochemistry, mechanisms of selected reactions, Reactive intermediates, oxidation, Reduction, CC bond formations, synthesis of some useful naturalproducts
CHM609A	PRINCIPLES OF ORGANIC CHEMISTRY	3-0-0-0-9	Stereochemistry, mechanisms of selected reactions, Reactive intermediates, oxidation, Reduction, CC bond formations, synthesis of some useful natural products
CHM611	PHYSICAL ORGANIC CHEMISTRY	3-0-0-0-4	Pericyclic Reactions: Conservation of orbital symmetry, and Woodward and Hoffmann rules. Cycloadditions, Electrocyclizations, Sigmatropic rearrangements, and Chelotropic reactions. Orbital overlap effects in chemical processes. Stereoelectronic Effects in Organic Chemistry: Acetals, Esters, Amides and related functions. Reactions at sp3, sp2, and sp carbons. Examples in synthesis and biological processes. FelkinAhn model, Houk model, Cieplakmodel, EFOE model, and Cationcomplexation model as applied to Facial selectivity.Reactive Intermediates: (5)Carbonium ions, carbanions, and radicals (formation, rearrangement, and further reactions inreference to Baldwin rules for ringclosure) Chemical Equilibria and Chemical Reactivity: (4) Correlation of reactivity with structure, Hammett equation, substituent constants and reaction constants Chemical Kinetics and Isotope Effects: (4)Various types of catalysis and isotope effects. Importance in the elucidation of organic reaction mechanisms. Electron Transfer Reactions: (3) Theoretical basis, Examples of photoinduced and chemicallyinduced electron transfer reactions (PET and CET). Organic Photochemistry: (6) Energy and electronic spin states, Spectroscopic transitions, photo physical processes, fluorescence and phosphorescence, energy transfer and electron transfer, and properties of excited states, Representative photochemical reactions of carbonyl compounds, olefins, andaromatic compounds. Miscellaneous: (3)A(1,2) and A (1,3) strain, Captodative effect, Hammonds postulate, CurtinHammett principle, and thermodynamic and kinetic control of reactions. **Course Reference**: 1. Isaacs, N. S., Physical Organic Chemistry; 2. Lowry and Richardson, Mechanism and Theory in Organic Chemistry; 3. Deslongchamps, P., Stereoelectronic Effects in Organic Chemistry
CHM611A	PHYSICAL ORGANIC CHEMISTRY	3-0-0-0-9	Pericyclic Reactions: Conservation of orbital symmetry, and Woodward and Hoffmann rules. Cycloadditions, Electrocyclizations, Sigmatropic rearrangements, and Chelotropic reactions. Orbital overlap effects in chemical processes. Stereoelectronic Effects in Organic Chemistry: Acetals, Esters, Amides and related functions. Reactions at sp3, sp2, and sp carbons. Examples in synthesis and biological processes. FelkinAhn model, Houk model, Cieplakmodel, EFOE model, and Cationcomplexation model as applied to Facial selectivity. Reactive Intermediates:

			Carbonium ions, carbanions, and radicals (formation, rearrangement, and further reactions inreference to Baldwin rules for ringclosure) Chemical Equilibria and Chemical Reactivity: (4) Correlation of reactivity with structure, Hammett equation, substituent constants and reaction constants Chemical Kinetics and Isotope Effects: (4) Various types of catalysis and isotope effects. Importance in the elucidation of organic reaction mechanisms. ElectronTransfer Reactions: (3) Theoretical basis, Examples of photoinduced and chemically induced electron transfer reactions (PET and CET). Organic Photochemistry: (6) Energy and electronic spin states, Spectroscopic transitions, photophysical processes, fluorescence and phosphorescence, energy transfer and electron transfer, and properties of excited states, Representative photochemical reactions of carbonyl compounds, olefins, andaromatic compounds. Miscellaneous: (3)A(1,2) and A (1,3) strain, Captodative effect, Hammonds postulate, CurtinHammett principle, and thermodynamic and kinetic control of reactions. **Course Reference**: 1. Isaacs, N. S., Physical Organic Chemistry; 2. Lowry and Richardson, Mechanism and Theory in Organic Chemistry; 3. Deslongchamps, P, Stereolectronic Effects in Organic Chemistry.
CHM612	FRONTIERS IN ORGANIC CHEMISTRY	3-0-0--4	Asymmetric Synthesis: Including organo and metal-based catalysis Synthesis using Organometallic Chemistry: Transition and main group elements basedreactions involving region, stereo, and enantioselective reactions and application inorganic synthesis. Supramolecular Chemistry, Combinatoria l Chemistry, etc. Green Chemistry, Glycobiology, Synthetic aspects using Domino reactions, Principles of atom economy with examples, Templated and solid supported Organic Synthesis. **Course Reference**: 1. M. B. Smith Organic Synthesis Wavefunction, Inc 2000; 2. HJ. Schmalz, T. Wirth Organic Synthesis Highlights, 2003; 3. J. Tsuji, Transition metal reagents and catalyst innovations in organic synthesis JohnWiley & Sons, Ltd, New York, 2000; 4. T. K. Lidhorst, Essentiall of carbohydrate chemistry and biochemistry, WileyVCH, 2006
CHM612A	FRONTIERS IN ORGANIC CHEMISTRY	3-0-0-0-9	Asymmetric Synthesis: Including organo and metal -based catalysis Synthesis using Organometallic Chemistry: Transition and main group elements basedreactions involving region, stereo, and enantioselective reactions and application inorganic synthesis. Supramolecular Chemistry, Combinatoria l Chemistry, etc. Green Chemistry, Glycobiology, Synthetic aspects using Domino reactions, Principles of atom economy with examples, Templated and solid supported Organic Synthesis. **Course Reference**: 1.M. B. Smith Organic Synthesis Wavefunction, Inc 2000; 2. HJ. Schmalz, T. Wirth Organic Synthesis Highlights, 2003; 3.J. Tsuji, Transition metal reagents and catalyst innovations in organic synthesis JohnWiley& Sons, Ltd, New York, 2000; 4.T. K. Lidhorst, Essentiall of carbohydrate chemistry and biochemistry,

			WileyVCH, 2006
CHM614	ORGANIC PHOTOCHEMISTRY	3-0-0--4	An overview of basic concepts of photochemistry Energy transfer; theoretical aspects of organic photochemistry; reaction mechanisms; photoreduction and photosubstitution reactions; photocyclo additions; photoisomerizations; photo fragmentation and elimination reactions; photolytic deprotection and activation of functional groups.Singlet oxygen: generation and reactions; photoinduced electron transfer basic concepts, illustrative examples of application to organic synthesis; photochemistry in organized media. Nanosecond and picoseconds studies of organic photoreactions. **Course Reference**: 1. Modern Molecular Photochemistry by N. J. Turro; 2. Organic Photochemistry by J. M. Coxan and B. Halton Essentials of Molecular Photochemistry by A. Gilbert and J. Baggot; 3. Organic Photochemistry and Photobiology, CRC Handbook, Edited by W. M. Horspool and P.S. Song.
CHM616	CHEMISTRY OF ORGANOMETALLIC COMPOUNDS	3-0-0--4	Introduction: History of organometallic chemistry; Werner complexes; Coordination number and geometry; Crystal field theory and ligand field theory; Bonding and molecular orbitals. Ligands Bonding Types, Charges, and Donor Electrons; Ligand: chelate effect and heptaciy; 18electron rule: Usefulness and limitationLewis Base Ligands: Halide donors, Oxygen ligands, Sulphur ligands, Nitrogen ligands: R3N,R2N, RN2; Tris(pyrazolyl) borate, A Few Biologically Important NLigands: imidazole, purine, porphyrine Carbonyls Phosphines bound carbon ligands: hydrides, alkyls, arylsbonded carbon ligands: alkene, alkyne, allyl, diene, arenes, arenes, metalacyles, Metallocene and sandwich complexes/bonded carbon ligands: carbenes, carbines Bimetallic complexes and Metal Clusters, Metalmetal bond in bimetallic complexes; Clusters; Isolobal analogy; Metal nanoparticles Elementary organometallic reactions (6)Ligand substitutions; Oxidative addition; Reductive elimination; Intramolecular insertions/eliminations; Nucleophillic/Electrophillic attacks on coordinated ligands. Homogeneous catalysis and Catalysts (10) Introduction; Alkene isomerization; Hydrogenation; Hydroformylation; Monsanto acetic acidprocess; Alkene polymerization; Cross coupling reactions; Metathesis; CH activation andfunctionalization; Oxidation of olefins; Metal Clusters and catalysis Physical methods in Organometallic chemistry (6)1H NMR spectroscopy; 13C NMR spectroscopy; 31P NMR spectroscopy; Dynamic NMR, Mass spectroscopy, Isotope effect. Bioinspired Organometallic chemistry (5) Introduction, Coenzyme B12, Nitrogen fixation; Nickel enzyme; **Course Reference**: 1. J. Tsuji, Transition metal reagents and catalyst innovations in organic synthesis JohnWiley & Sons, Ltd, New York, 2000; 2. M. B. Smith Organic Synthesis Wavefunction, Inc 2000; 3. HJ. Schmalz, T. Wirth Organic Synthesis Highlights, 2003; 4. K. C. Nicolaou, Classics in Total Synthesis Vols IIII, WileyVCH, 1996; 2003; 2011; 5. The Organometallic Chemistry of the Transition Metals by Robert Crabtree (3rd Edition, Wiley); 6. The Principles and

			Applications of Transition Metal Chemistry, by Collman, Hegedus, Norton and Finke (2nd eds, University Science Books); 7. Organometallics by, Christoph Elschenbroich. (3rd Edition, Wiley)
CHM616A	CHEMISTRY OF ORGANOMETALLIC COMPOUNDS	3-0-0-0-9	Introduction: History of organometallic chemistry; Werner complexes; Coordination number and geometry; Crystal field theory and ligand field theory; Bonding and molecular orbitals.Ligands Bonding Types, Charges, and Donor Electrons; Ligand: chelate effect and heptaciy; 18electron rule: Usefulness and limitationLewis Base Ligands: Halide donors, Oxygen ligands, Sulphur ligands, Nitrogen ligands: R3N,R2N, RN2; Tris(pyrazolyl) borate, A Few Biologically Important NLigands: imidazole,purine, porphyrine Carbonyls Phosphines bound carbon ligands: hydrides, alkyls, arylsbonded carbon ligands: alkene, alkyne, allyl, diene, arenes, arenes, metalacylesMetallocene and sandwich complexes/bonded carbon ligands: carbenes, carbines Bimetallic complexes and Metal Clusters (3) Metalmetal bond in bimetallic complexes; Clusters; Isolobal analogy; Metal nanoparticles Elementary organometallic reactions (6)Ligand substitutions; Oxidative addition; Reductive elimination; Intramolecular insertions/eliminations; Nucleophillic/ Electrophillic attacks on coordinated ligands.Homogeneous catalysis and Catalysts Introduction; Alkene isomerization; Hydrogenation; Hydroformylation; Monsanto acetic acidprocess; Alkene polymerization; Cross coupling reactions; Metathesis; CH activation and functionalization; Oxidation of olefins; Metal Clusters and catalysis Physical methods in Organometallic chemistry (6)1H NMR spectroscopy; 13C NMR spectroscopy; 31P NMR spectroscopy; Dynamic NMR, Massspectroscopy, Isotope effect.Bioinspired Organometallic chemistry (5)Introduction, Coenzyme B12, Nitrogen fixation; Nickel enzyme; **Course Reference**: 1. J. Tsuji, Transition metal reagents and catalyst innovations in organic synthesis JohnWiley & Sons, Ltd, New York, 2000; 2. M. B. Smith Organic Synthesis Wavefunction, Inc 2000; 3. HJ. Schmalz, T. Wirth Organic Synthesis Highlights, 2003; 4. K. C. Nicolaou, Classics in Total Synthesis Vols IIII, WileyVCH, 1996; 2003; 2011; 5. The Organometallic Chemistry of the Transition Metals by Robert Crabtree (3rd Edition, Wiley); 6. The Principles and Applications of Transition Metal Chemistry, by Collman, Hegedus, Norton and Finke (2nd eds, University Science Books); 7. Organometallics by Christoph Elschenbroich. (3rd Edition, Wiley).
CHM621	CHEMICAL BINDING	3-0-0-0-4	Review of basic principles of quantum theory and atomic structure. Introduction to chemicalbonding and weak intermolecular forces. (4) Electronic structure of many electron atoms and variation principle. Electronic structure ofdiatomic molecules. Born Oppenheimer approximation, H2+ ion, approximate molecularorbital (MO) theory of ground and excited states of H2+, homo and heteronuclear diatomic molecules, electronic term symbols, valence bond (VB) theory of diatomic molecules, comparison of VB and MO

			theories. HartreeFock theory of atoms and extension to molecules. Self Consistent Field (SCF) wavefunctions for diatomic molecules, configuration interaction (CI) wave functions. Electronic structures of polyatomic molecules. SCFMO treatment of closed shell systems. Basis functions. SCFMO treatment of simple molecules like H2O, NH3, C2H6, C2H4 etc. Population analysis, Potential energy surface and equilibrium geometry, molecular vibrational frequencies. Koopmans; and Brillouin's theorems. Brief introduction to electron correlation. MllerPlesset (MP) perturbation theory and CI calculations. Virial and Hellmann Feynman theorems. Hckel theory applied to conjugated molecules. Elements of Density Fuctional Theory (DFT), Semiempirical methods (extended Hckel andCNDO), Molecular mechanics, Topological characteristics of electron density. **Course Reference**: 1. I.N. Levine, Quantum Chemistry, Fifth edition, Pearson Education (2000); 2. F.L. Pilar, Elementary Quantum Chemistry, Second edition, McGrawHill (1990); 3. J.P. Lowe, Quantum Chemistry, Second edition, Academic Press (1993); 4. P.W. Atkins and R.S. Friedman, Molecular Quantum Mechanics, Third edition, OxfordUniversityPress (1997); 5 A. Szabo and N. S. Ostlund, Modern Quantum Chemistry, Dover (1996).
CHM621A	CHEMICAL BINDING	3-0-0-0-9	Intoroduction, The origin of quantum numbers, some constant potential problems, commutation relationships, the atomic self consistent field (SCF), Hartree and Hartree Fock methods. Screening effects Staters rules and electron correlation overlap hybridisation and examples thereof. Directed valence inspace. Observable features of the chemical bond Chemical Binding.
CHM622	CHEMICAL KINETICS	3-0-0--4	Phenomenological kinetics: Simple and complex systems including opposing, concurrent and consecutive reactions, Rate law and mechanism, relation with thermodynamics, Precision in rate measurement, data analysis, Special experimental methods including flash photolysis, shock tube, molecular beam andrelaxation techniques Oscillatory reactions. Theories of reaction rates: bimolecular reactions, rate coefficient, activation energy, potentialenergy surfaces, trajectory methods and transition state theory. Unimolecular andtermolecular reactions, Applications: photochemistry, solution kinetics, homogeneous and heterogeneous catalysisand enzyme kinetics. **Course Reference**: 1. K. J. Laidler, Chemical Kinetics, 3rd Ed. Harper & Row, New York, 1987; 2. R. D. Levine and R. B. Bernstein, Molecular Reaction Dynamics and Chemical Reactivity, Oxford Univ. Press, Oxford, 1987; 3. J. I. Steinfeld, J. S. Francisco, W. L. Hase, Chemical Kinetics and Dynamics, 2nd ed. Prentice Hall, NJ 1999.
CHM626	SOLID STATE CHEMISTRY	3-0-0--4	Chemical crystallography: Introduction, Space lattice, Crystal point groups, space group (working knowledge), Stereographic projections, Packing in solids, Crystal

			structures of representative systems, Silicates and Zeolites, Cements, Glasses, Quasicrystals, Nanostructures. Bonding in solids and Crystal energetic, Crystal classifications, Madelung constant and Lattice energy. Characterization techniques (working knowledge) for solids, Xray diffraction, Electron microscopy (SEM, TEM, AFM), Thermal techniques (TG, DTA, DSC), Spectroscopic techniques (Mossbauer, IR, UVVIS) and Physical propertymeasurement techniques (Magnetic momentsVSM /SQUID, Electrical resistivity V Two / Fourprobe methods and thermal conductivity, Optical band gap, XPES, XAS). Electronic properties and Band theory of solids Free electron model, Metals, semiconductors and insulators, doped semiconductors Solid state ionics.Defects, Nonstoichiometry and Diffusion Point defects, Dislocations, Extended defects, Clusters and aggregates, Color centres, Nonstoichiometry of compounds, Diffusion mechanisms, Ficks law, Kirkenall effect.Phase transitions (06)Critical phenomena, variety of phase transitions (Ordered disorder, Martensiteaustenite, Spinoidal decompositions etc), Liquid crystals, Structure property relations (magnetic,electrical, superconductivity, optical and thermal). Preparative techniques Powder synthesis by conventional and modern chemical methods, Reactivity of solids, Decomposition mechanisms, Powder processing (sintering and diffusion processes), Tailoring of solids, Special methods for single crystal growth and thin films depositions. **Course Reference**: 1. A R. West, Solid state chemistry and its applications, John Wiley & Sons, 1989; 2. L Smart and E. Moore, Solid state chemistry, Chapman and Hall , 1992; 3. A K. Cheetham and P. Day, Solid state chemistry compounds, Clarendon Press,Oxford 1992; 4. C N. R. Rao and J. Gopalkrishanan, New directions in solid state chemistry,Cambridge Univ. Press 1997; 5. R E. Newnham, Structure property relations, SpringerVerlag, 1975; 6. P. A. Cox,Electronic structure and chemistry of solids, Oxford Univ. Press 1987.
CHM626A	SOLID STATE CHEMISTRY	3-0-0-0-9	Chemical crystallography Introduction, Space lattice, Crystal point groups, space group (working knowledge), Stereographic projections, Packing in solids, Crystal structures of representative systems, Silicates and Zeolites, Cements, Glasses, Quasicrystals, Nanostructures.Bonding in solids and Crystal energetic, Crystal classifications, Madelung constant and Lattice energy.Characterization techniques (working knowledge) for solids, Xray diffraction, Electron microscopy (SEM, TEM, AFM), Thermal techniques (TG, DTA,DSC), Spectroscopic techniques (Mossbauer, IR, UVVIS) and Physical property measurement techniques (Magnetic momentsVSM /SQUID, Electrical resistivity V Two / Fourprobe methods and thermal conductivity, Optical band gap, XPES, XAS).Electronic properties and Band theory of solids (04)Free electron model, Metals, semiconductors and insulators, doped semiconductors Solid state ionics. Defects, Nonstoichiometry and Diffusion Point defects, Dislocations, Extended defects, Clusters and aggregates, Color centres,

			Nonstoichiometry of compounds, Diffusion mechanisms, Ficks law, Kirkenall effect. Phase transitions (06)Critical phenomena, variety of phase transitions (Ordered disorder, Martensiteaustenite, Spinoidal decompositions etc), Liquid crystals, Structure property relations (magnetic,electrical, superconductivity, optical and thermal).Preparative techniques Powder synthesis by conventional and modern chemical methods, Reactivity of solids, Decomposition mechanisms, Powder processing (sintering and diffusion processes), Tailoring of solids, Special methods for single crystal growth and thin films depositions. **Course Reference**: 1. A R. West, Solid state chemistry and its applications, John Wiley & Sons, 1989; 2. L Smart and E. Moore, Solid state chemistry, Chapman and Hall , 1992; 3. A K. Cheetham and P. Day, Solid state chemistry compounds, Clarendon Press, Oxford 1992; 4. C N. R. Rao and J. Gopalkrishanan, New directions in solid state chemistry,Cambridge Univ. Press 1997; 5. R E. Newnham, Structure property relations, Springer Verlag, 1975; 6. P. A. Cox,Electronic structure and chemistry of solids, Oxford Univ. Press 1987.
CHM629	PRINCIPLES OF PHYSICAL CHEMISTRY	3-0-0--4	Atomic and Molecular structure, Molecular Spectroscopy, Concepts of Statistical Thermodynamics, Electrochemistry, Chemical Kinetics, Photochemistry
CHM629A	PRINCIPLES OF PHYSICAL CHEMISTRY	3-0-0-0-9	Atomic and Molecular structure, Molecular Spectroscopy, Concepts of Statistical Thermodynamics, Electrochemistry, Chemical Kinetics, Photochemistry.
CHM631	APPLICATIONS OF MODERN INSTRUMENTAL METHODS	3-0-0--4	Applications of multinuclear NMR (1H, 13C, 29Si, 31P, 19F, 11B, 119Sn etc.). ESR, ENDOR (Electron Nuclear Double Resonance), Mossbauer and photoelectron spectroscopy towards structure elucidation of inorganic, organic and biologically important compounds.
CHM631A	APPLICATIONS OF MODERN INSTRUMENTAL METHODS	3-0-0-0-9	Applications of multinuclear NMR (1H, 13C, 29Si, 31P, 19F, 11B, 119Sn etc.). ESR, ENDOR (Electron Nuclear Double Resonance), Mossbauer and photoelectron spectroscopy towards structure elucidation of inorganic, organic and biologically important compounds
CHM632	ENZYME REACTIONS MECHANISM AND ENZYME KINETICS	3-0-0--4	Enzyme kinetics of single and multiple substrate systems including Enzyme assays and inhibition (15 lectures). Cooperativity and multienzyme systems (4 lectures). Enzyme structure and identification of active site residues labelin,

			chemical modification and mutagenesis (6 lectures). Enzyme Mechanisms. Methods of study and mechanisms of some enzymes like Serine proteases, polymerases, ribonucleases, lysozyme and ribonucleotide reductases (radical enzyme) (15 lectures). Mechanism based enzyme inhibition and drugs fluorouracil for thymidylate synthase (2lectures). **Course Reference**: 1. Allan Ferhst, Structure and Mechanism in Protein Science: A Guide to Enzyme Catalysisand Protein Folding; 2. N. C. Price and E. Stevens, Fundamentals of Enzymology: The Cell and Molecular Biology of Catalytic Proteins; 3. I. H. Segel, Biochemical calculations, How to Solve Mathematical Problems in General Biochemistry, 2nd Edition.
CHM636	PHYSICAL PHOTOCHEMISTRY	3-0-0--4	1. Theory of electronic absorption spectra, Beers law, Absorption crosssection, Solvatochromism; 2. Radiative and nonradiative transitions, Vibrational relaxation, Internal conversion, Intersystem crossing ; 3. Fluorescence, Phosphorescence, Various photophysical processes, Solvent effect one mission, Lippert equation, Dynamic stokes shift, Dynamic and static quenching, Stern Volmer equation, Forster resonance energy transfer and theory, Fluorescence anisotropy and Perrin equation, Excited state proton/electron transfer, Excimer andexciplex; 4. Laser fundamentals, Stimulated emission, Population inversion, Light amplification, Pulsed laser: cavity dumping, Qswithching, modelocking; 5. Spectroscopic techniques, Spectrophotometer, Spectrofluorimeter, Time correlated single photon counting, Transient absorption, Streak camera, Fluorescence upconversion; 6. Single molecule spectroscopy, Fluorescence correlation spectroscopy, Proteinfluorescence. **Course Reference**: 1. Nicholas J. Turro, Modern Molecular Photochemistry; 2. K. K. RohatgiMukherjee, Fundamentals of Photochemistry; 3. J. R. Lakowicz, Principles of Fluorescence Spectroscopy; 4. W. T. Silvast, Laser Fundamentals
CHM636A	PHYSICAL PHOTOCHEMISTRY	3-0-0-0-9	1. Theory of electronic absorption spectra, Beers law, Absorption crosssection,Solvatochromism; 2. Radiative and nonradiative transitions, Vibrational relaxation, Internal conversion, Intersystem crossing; 3. Fluorescence, Phosphorescence, Various photophysical processes, Solvent effect onemission, Lippert equation, Dynamic stokes shift, Dynamic and static quenching, SternVolmer equation, Forster resonance energy transfer and theory, Fluorescence anisotropy and Perrin equation, Excited state proton/electron transfer, Excimer andexciplex; 4. Laser fundamentals, Stimulated emission, Population inversion, Light amplification, Pulsed laser: cavity dumping, Qswithching, modelocking; 5. Spectroscopic techniques, Spectrophotometer, Spectrofluorimeter, Time correlated single photon counting, Transient absorption, Streak camera, Fluorescence upconversion; 6. Single molecule spectroscopy, Fluorescence correlation spectroscopy, Protein fluorescence. **Course Reference**: 1. Nicholas J. Turro, Modern Molecular

			Photochemistry; 2. K. K. RohatgiMukherjee, Fundamentals of Photochemistry; 3. J. R. Lakowicz, Principles of Fluorescence Spectroscopy; 4. W. T. Silvast, Laser Fundamentals.
CHM637	MOLECULAR SPECTROSCOPY	3-0-0--4	1. Group theory Review of point groups, permutation inversion and molecular symmetry groups; 2. Interaction of radiation and matter,Qualitative aspects, Einstein A, B coefficients, absorptionemission and lineshapes; 3. Rotational Spectroscopy Rigid body, selection rules, vibrational angular momentum, tops; 4. Vibrational Spectroscopy (8) Normal modes, selection rules, Fermi and Coriolis perturbations, polyatomic molecules; 5. Electronic Spectroscopy Introduction, symmetry aspects, vibronic effects; 6. Advanced topics Coupling of rotational and vibrational motions, nonrigid systems, high resolution and highly excited states, Wilson Howard Watson Hamiltonian, time dependent viewpoint. **Course Reference**: 1. Bernath, Spectra of Atoms and Molecules, 1995; 2. Bunker & Jensen, Molecular Symmetry & Spectroscopy, 1998; 3. Papousek & Aliev, Molecular VibrationalRotational Spectra, 1982; 4. Hollas, Modern Spectroscopy, 2004; 5. McHale, Molecular Spectroscopy, 1998.
CHM637A	MOLECULAR SPECTROSCOPY	3-0-0-0-9	1. Group theory: Review of point groups, permutation inversion and molecular symmetry groups; 2. Interaction of radiation and matter Qualitative aspects, Einstein A, B coefficients, absorption emission and lineshapes; 3. Rotational Spectroscopy Rigid body, selection rules, vibrational angular momentum, tops; 4. Vibrational Spectroscopy Normal modes, selection rules, Fermi and Coriolis perturbations, polyatomic molecules; 5. Electronic Spectroscopy Introduction, symmetry aspects, vibronic effects; 6. Advanced topics Coupling of rotational and vibrational motions, nonrigid systems, high resolution and highly excited states, Wilson HowardWatson Hamiltonian, time dependent viewpoint. **Course Reference**: 1. Bernath, Spectra of Atoms and Molecules, 1995; 2. Bunker & Jensen, Molecular Symmetry & Spectroscopy, 1998; 3. Papousek & Aliev, Molecular Vibrational Rotational Spectra, 1982; 4. Hollas, Modern Spectroscopy, 2004; 5. McHale, Molecular Spectroscopy, 1998.
CHM641	ADVANCED INORGANIC CHEMISTRY I	3-0-0--4	An advanced course on the physical principles of inorganic chemistry with illustrations from the chemistry of transition and nontransition elements.
CHM646	BIO-INORGANIC CHEMISTRY	3-0-0-0-4	1. Mineral Origin of life. Archaeal, Eucarial and Bacterial domain. (3 Lectures); 2. Transition metal ions in biology. Metalobiomolecules. Electron carriers, oxygen carriers, enzymes. Biogeoinorganic chemistry, environment. (10 Lectures); 3. Specific examples: Hemoglobin, Myoglobin, Hemocyanin, Hemrythrin cytochromes, FeS proteins, Cytochrome P450, Nitrophorin, NOsynthase, peroxidase, catalase, Ferritin, cytochrome oxidase, cerulplasmin, bluecopper proteins, di and tricopper proteins. Other

			enzymes like, hydrogenase, methane monooxygenase, dioxygenases, dehydratase, nitrogenase, molybdenum containing oxidase and reductase class of enzymeslike sulfite oxidase, xanthine oxidase, nitrate reductase, DMSO reductase, tungsten containing formate dehydrogenase and tungsten bearing hyper thermophilic and thermophilic enzymes. Zn enzymes like carbonican hydrase, carboxypeptidase, DNA and RNA polymerases, Nickel containing F430, role of manganese in water splitting. (15 Lectures); 4. Active site analogue reaction models and structural models of these enzymes. (5 Lectures); 5. Environmental chemistry, auto exhaust, arsenic and other heavymetal pollutions. (2 Lectures); 6. Forensic chemistry; inorganic chemistry in medicine, platinum complexes, MoS complexes as anticancer drugs. **Course Reference**: 1. Principles of Bioinorganic Chemistry, S. J. Lippard and J. M. Berg, University Science Books, Mill Valley, 1994; 2. Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, W. Kaim and B. Schwederski, John Wiley & Sons Inc., 1994.
CHM646A	BIO-INORGANIC CHEMISTRY	3-0-0-0-9	1. Mineral Origin of life. Archaeal, Eucarial and Bacterial domain. (3 Lectures); 2. Transition metal ions in biology. Metalobiomolecules. Electron carriers, oxygencarriers, enzymes. Biogeoinorganic chemistry, environment. (10 Lectures); 3. Specific examples: Hemoglobin, Myoglobin, Hemocyanin, Hemrythrincytochromes, FeS proteins, Cytochrome P450, Nitrophorin, NOsynthase, peroxidase, catalase, Ferritin, cytochromeC oxidase, cerulplasmin, bluecopper proteins, di and tricopper proteins. Other enzymes like, hydrogenase, methane monooxygenase, dioxygenases, dehydratase, nitrogenase, molybdenum containing oxidase and reductase class of enzymes like sulfite oxidase, xanthine oxidase, nitrate reductase, DMSO reductase, tungsten containing formate dehydrogenase and tungsten bearing hyperthermophilic and thermophilic enzymes. Zn enzymes like carbonicanhydrase, carboxypeptidase, DNA and RNA polymerases, Nickel containingF430, role of manganese in water splitting. (15 Lectures)4. Active site analogue reaction models and structural models of theseenzymes. (5 Lectures); 5. Environmental chemistry, auto exhaust, arsenic and other heavymetal pollutions. (2 Lectures); 6. Forensic chemistry; inorganic chemistry in medicine, platinum complexes, MoScomplexes as anticancer drugs. **Course Reference**: 1. Principles of Bioinorganic Chemistry, S. J. Lippard and J. M. Berg, University Science Books, Mill Valley, 1994; 2. Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, W. Kaim and B. Schwederski, John Wiley & Sons Inc., 1994.
CHM648	THE CHEMISTRY OF METAL-CARBON BOND: STRUCTURE REACTIVITY & APPLICATIONS	3-0-0--4	Introduction to Organometallics: Bonding, Types of Ligands, and some basics concepts like isoelectronic and isolobal analogy Characterization techniques of Organometallic compounds (NMR and IR spectroscopy and Mass spectrometry) Representative chemistry of main group

			Organometallics Organometallic chemistry of lithium and magnesium: synthesis, structures, fluxionality and reactivity Chemistry of Aluminum: Aluminum alkyls. Use of aluminum alkyls in polymerization of olefins. Organometallic chemistry of transition metals bonded ligands: Metal alkyls, aryls and hydrides. Stability, preparation and reactivity.Metal carbonyls / Metal phosphines / metal nitrosyls / metal isocyanide: structures,reactivity and bonding.Metal carbenes, metalcarbynes, Fischer carbenes, Schrock, carbenes, complexes with Nheterocycliccarbenes (NHCs), bonded ligand: Metalolefins, alkyls metal alkynes, dienes, Cp and Cp*, structure, bonding and reactivity.Reactions in Organometallic Chemistry: Oxidative addition, reductive elimination, insertion,elimination, and migrationApplications of organometallics in organic synthesis C bond coupling reactions (Heck, sangoshira, Suzuki) Reduction using transition metal hydrides, asymmetric hydrogenation. Olefin metathesis Most of the material for this course will be accessed from primary literature viz., Journalarticles. Some text books that will be followed are as follows- **Course Reference**: 1. Elschenbroich, C.; Salzer, A.; Organometallics: A Concise Introduction 3rd Edn. John Wileyand sons 2005; 2. B D Gupta and A J. Elias, Basic Organometallic Chemistry: Concepts, Syntheses and Applications, First Edition, Universities Press, 2010; 3. Douglas, B.; McDaniel, D.; and Alexander, J. Concepts and Models of Inorganic Chemsitry 3rdEdn. John Wiley, New York. 1993; 4. Rober t H. Crabtree, The Organometallic Chemistry of the Transition Metals, John Wiley andSons, 4th edn. John Wiley and sons 2005.
CHM648A	THE CHEMISTRY OF METAL-CARBON BOND: STRUCTURE REACTIVITY & APPLICATIONS	3-0-0-0-9	Introduction to Organometallics: Bonding, Types of Ligands, and some basics concepts like isoelectronic and isolobal analogy Characterization techniques of Organometallic compounds (NMR and IR spectroscopy andMass spectrometry) Representative chemistry of main group Organometallics Organometallic chemistry of lithium and magnesium: synthesis, structures, fluxionality and reactivity Chemistry of Aluminum: Aluminum alkyls. Use of aluminum alkyls in polymerization of olefins. Organometallic chemistry of transition metals bonded ligands: Metal alkyls, aryls and hydrides. Stability, preparation and reactivity. Metal carbonyls / Metal phosphines / metal nitrosyls / metal isocyanide: structures,reactivity and bonding. Metal carbenes, metalcarbynes, Fischer carbenes, Schrock, carbenes, complexes with Nheterocycliccarbenes (NHCs), bonded ligand: Metal olefins, alkyls metal alkynes, dienes, Cp and Cp*, structure, bonding and reactivity.Reactions in Organometallic Chemistry: Oxidative addition, reductive elimination, insertion,elimination, and migration Applications of organometallics in organic synthesisCC bond coupling reactions (Heck, sangoshira, Suzuki)Reduction using transition metal hydrides, asymmetric hydrogenation.Olefin metathesis Most of the material for this course will be accessed from primary literature viz., Journalarticles. Some

			text books that will be followed are as follows- **Course Reference**: 1. Elschenbroich, C.; Salzer, A.; Organometallics: A Concise Introduction 3rd Edn. John Wileyand sons 2005; 2 B. D. Gupta and A. J. Elias, Basic Organometallic Chemistry: Concepts, Syntheses andApplications, First Edition, Universities Press, 2010; 3. Douglas, B.; McDaniel, D.; and Alexander, J. Concepts and Models of Inorganic Chemsitry 3rdEdn. John Wiley, New York. 1993; 4. Rober t H. Crabtree, The Organometallic Chemistry of the Transition Metals, John Wiley andSons, 4th edn. John Wiley and sons 2005.
CHM649	PRINCIPALES OF INORGANIC CHEMISTRY	3-0-0--4	Principles of modern inorganic chemistry discussion of the chemistry of nontransition elements, Coordination Chemistry, organometallic chemistry, Inorganic chemistry of biological systems.
CHM649A	PRINCIPALES OF INORGANIC CHEMISTRY	3-0-0-0-9	Principles of modern inorganic chemistry discussion of the chemistry of nontransition elements, Coordination Chemistry, organometallic chemistry, Inorganic chemistry of biological systems.
CHM650	STATISTICAL MECHANICS & ITS APPL. TO CHEMISTRY	3-0-0--4	Course description: Thermodynamics, Statistical Mechanics of noninteracting systems,interacting systems, and nonequilibrium systemsCourse Details; 1. Equilibrium Thermodynamics: Thermodynamic Equilibrium state, laws ofthermodynamics, axiomatic formulation of thermodynamics, thermodynamic potentials,stability criteria, phase equilibria (4 lectures); 2. Ensembles in Statistical Mechanics: Ensemble postulate and ergodicity, microcanonical,canonical and grand canonical ensembles, quantum and classicalpartition functions, phase space, fluctuations (6 lectures); 3. Noninteracting systems: Factorization of the partition function, quantum correlations, collective modes, occupation numbers, collections of fermions, bosons,photons, classical deal gas of spinless particles, molecular partition functions, ideal paramagnets. (6 lectures); 4. Interacting Systems Classical Liquids Interparticle potentials, Configurational Partition functions, distributions, pair correlation function, neutron scatteringexperiments, Virial equation, Meyer cluster diagrams (6 lectures); 5. Interacting Systems, Computer Simulations Ensemble averages, ergodicity,random numbers, Monte Carlo methods, Molecular Dynamics, constant temperatureMD. (5 lectures); 6. Interacting Systems 3: Phase Transitions in Lattice models Lattice gas, Ising Model, order parameter, Mean Field theory, Renormalization group theory (6 lectures); 7. Nonequilibrium Statistical Mechanics (6 lectures) Linear Response theory, fluctuation dissipation theorem, time correlation functions, applications to transport phenomena. **Course Reference**: 1. D.A. McQuarrie, Statistical Mechanics; 2. David Chandler, Introduction to Modern Statistical Mechanics; 3. K.L. Huang, Statistical Mechanics; 4. B. Widom, Statistical Mechanics: A concise introduction for chemists

CHM650A	STATISTICAL MECHANICS & ITS APPL. TO CHEMISTRY	3-0-0-0-9	Course description: Thermodynamics, Statistical Mechanics of noninteracting systems, interacting systems, and nonequilibrium systems Course Details 1. Equilibrium Thermodynamics: Thermodynamic Equilibrium state, laws ofthermodynamics, axiomatic formulation of thermodynamics, thermodynamic potentials,stability criteria, phase equilibria (4 lectures); 2. Ensembles in Statistical Mechanics: Ensemble postulate and ergodicity, microcanonical,canonical and grand canonical ensembles, quantum and classical partition functions, phase space, fluctuations (6 lectures); 3. Noninteracting systems: Factorization of the partition function, quantum correlations,collective modes, occupation numbers, collections of fermions, bosons,photons, classical deal gas of spinless particles, molecular partition functions, idealparamagnets. (6 lectures); 4. Interacting Systems: Classical Liquids Interparticle potentials, Configurational Partition functions, distributions, pair correlation function, neutron scatteringexperiments, Virial equation, Meyer cluster diagrams (6 lectures); 5. Interacting Systems, Computer Simulations Ensemble averages, ergodicity, random numbers, Monte Carlo methods, Molecular Dynamics, constant temperatureMD. (5 lectures); 6. Interacting Systems 3 Phase Transitions in Lattice models Lattice gas Ising Model, order parameter, Mean Field theory, Renormalization group theory (6 lectures); 7. Nonequilibrium Statistical Mechanics (6 lectures) Linear Response theory, fluctuation dissipation theorem, time correlation functions, applications to transport phenomena. **Course Reference**: 1. D.A. McQuarrie, Statistical Mechanics2. David Chandler, Introduction to Modern Statistical Mechanics3. K.L. Huang, Statistical Mechanics4. B. Widom, Statistical Mechanics: A concise introduction for chemists
CHM651	CRYSTAL AND MOLECULAR STRUCTURE DETERMINATION	3-0-0--4	Generation of Xrays, monochromators, safety (1 Lecture)Concept of direct and reciprocal lattices, Braggs law of Xray diffraction in direct andreciprocal lattice, crystal systems, point groups, Bravais lattices(5 Lectures) Rotational axes of symmetry, screw axes, glide planes, equivalent points, systematicabsences, space groups (8 Lectures) Argand diagram, intensity data collection and quantitative aspects of Xray diffraction,temperature factor and scaling of data (10 Lectures).The phase problem, direct method of solving structures (8 Lectures). Patterson method, isomorphous replacement method (8 Lectures). Structure refinement and their critical evaluation (5 Lectures). **Course Reference**: 1. Xray Structure Determination A Practical Guide by G. H. Stout and H. L. Jensen, MacMillan N.Y. 1968; 2. Contemporary Crystallography, M. J. Buerger, McGrawHill, N.Y. 1970; 3. Crystal Structure Analysis A Primer J. P. Glusker and K. N. Trueblood, OUP, N.Y. 1985; 4. Structure Determination by Xary Crystallography, M. Ladd and R. Palmer, KluwerAcademic/Plenum, N.Y. 2003.
CHM651A	CRYSTAL AND MOLECULAR	3-0-0-0-9	Generation of Xrays, monochromators, safety (1 Lecture) Concept of direct and reciprocal lattices, Braggs law of Xray

	STRUCTURE DETERMINATION		diffraction in direct andreciprocal lattice, crystal systems, point groups, Bravais lattices(5 Lectures)Rotational axes of symmetry, screw axes, glide planes, equivalent points, systematicabsences, space groups (8 Lectures) Argand diagram, intensity data collection and quantitative aspects of Xray diffraction,temperature factor and scaling of data (10 Lectures)The phase problem, direct method of solving structures (8 Lectures) Patterson method, isomorphous replacement method(8 Lectures) Structure refinement and their critical evaluation (5 Lectures). **Course Reference**: 1. Xray Structure Determination A Practical Guide by G. H. Stout and H. L. Jensen, MacMillan, N.Y. 1968; 2. Contemporary Crystallography, M. J. Buerger, McGrawHill, N.Y. 1970; 3. Crystal Structure Analysis A Primer J. P. Glusker and K. N. Trueblood, OUP, N.Y. 1985; 4. Structure Determination by Xary Crystallography, M. Ladd and R. Palmer, KluwerAcademic/Plenum, N.Y. 2003
CHM654	SUPRAMOLECULAR CHEMISTRY	3-0-0-0-4	Introduction to the meaning of supramolecular chemistry, phenomenon of molecular recognitionand their quantification (2 Lectures); Building blocks of supramolecular chemistry acyclic receptors for neutral and chargedguests, macrocycles and crown ethers, macrobicycles and cryptands, macropolycycles, cucurbiturils and cyclodextrins (12 Lectures); Sensors and information processing, electrooptic phenomena, molecular machines (12Lectures); Amphiphilic molecules and their aggregation, Langmuir Blodgettry, molecular recognition atthe airwater interface. (3 Lectures); Discrete and polymeric metalorganic hybrid materials guest inclusion, catalysis and otherapplications. (12 Lectures); Future scopes (1 Lecture). **Course Reference**: 1. Supramolecular Chemistry: Concepts and Perspectives, J.M. Lehn, VCH, Weinheim, 1995; 2. Principles and Methods in Supramolecular Chemistry, H. J. Schneider and A. Yatsimirsky, Wiley, New York, 2000; 3. Supramolecular Chemistry, J. W. Steed and J. L. Atwood, John Wiley & Sons, Chichester,2009.
CHM654A	SUPRAMOLECULAR CHEMISTRY	3-0-0-0-9	Introduction to the meaning of supramolecular chemistry, phenomenon of molecular recognitionand their quantification (2 Lectures); Building blocks of supramolecular chemistry acyclic receptors for neutral and chargedguests, macrocycles and crown ethers, macrobicycles and cryptands, macropolycycles, cucurbiturils and cyclodextrins (12 Lectures); Sensors and information processing, electrooptic phenomena, molecular machines (12Lectures); Amphiphilic molecules and their aggregation, Langmuir Blodgettry, molecular recognition atthe airwater interface. (3 Lectures); Discrete and polymeric metalorganic hybrid materials guest inclusion, catalysis and otherapplications. (12 Lectures); Future scopes (1 Lecture). **Course Reference**: 1. Supramolecular Chemistry: Concepts and Perspectives, J.M. Lehn, VCH, Weinheim, 1995; 2. Principles and Methods in Supramolecular Chemistry, H. J. Schneider and A. Yatsimirsky, Wiley, New York, 2000; 3. Supramolecular Chemistry, J. W. Steed and J. L. Atwood,

			John Wiley & Sons, Chichester,2009.
CHM662	CHEMISTRY OF NATURAL PRODUCTS	3-0-0--4	Biosynthetic aspects and Synthesis of selected natural products of biological and structural importance: Discussions on synthetic methods, strategies towards these natural products mostly in chiral forms will be discussed in detail. The natural products include carbacycles and heterocyclic moieties containing structures ranging from memebered to macrocyles, and complex natural products such as Taxol, rapamycin, lejimailde B etc. **Course Reference**: 1. K. C. Nicolaou, Classics in Total Synthesis Vols IIII, WileyVCH, 1996; 2003; 2011T. 2. Hudlicky and J. W. Reed, The way of synthesis, WileyVCH, 2007; 3.E. J. Corey and XM. Cheng, The logic of chemical synthesis, JohnWiley & Sons, New York1989; 4. D.H. R. Barton, K. Nakanishi, O. MethCohn, Comprehensive natural products chemistry Vols 19, Elsevier, 1999
CHM662A	CHEMISTRY OF NATURAL PRODUCTS	3-0-0-0-9	Biosynthetic aspects and Synthesis of selected natural products of biological and structural importance: Discussions on synthetic methods, strategies towards these natural product smostly in chiral forms will be discussed in detail. The natural products include carbacycles and heterocyclic moieties containing structures ranging from memebered to macrocyles, and complex natural products such as Taxol, rapamycin, lejimailde B etc. **Course Reference**: 1.K. C. Nicolaou, Classics in Total Synthesis Vols IIII, WileyVCH, 1996; 2003; 2011; 2.T. Hudlicky and J. W. Reed, The way of synthesis, WileyVCH, 2007; 3. E. J. Corey and XM. Cheng, The logic of chemical synthesis, JohnWiley & Sons, New York1989; 4. D.H. R. Barton, K. Nakanishi, O. MethCohn, Comprehensive natural products chemistryVols 19, Elsevier, 1999.
CHM664	MODERN PHYSICAL METHODS IN CHEMISTRY	3-0-0-0-4	1. Symmetry and Group Theory: Group multiplication table, elements of a symmetry group,symmetry group classification, characters, group representation, The Great Orthogonality theorem, basis of representation, wave functions as bases of IR representations, symmetryadapted linear combinations, direct products, spectral transitions; 2. Interaction of light with matter, Einsteins coefficients, relationship of Einsteins coefficients with transition moments (no derivation) and transition probabilities, oscillator strength. BeerLambert law, relationship between Einsteins coefficients and total absorbance. Born Oppenheimer approximation, energy levels, potential energy curves, MO and term symbols, Franck Condon principle, symmetry and selection rules, spin and parity forbidden transitions, vibronic interaction; 3. Simple harmonic motion, anharmonicity, introduction of different coordinates (generalised, mass weighted generalized, internal and normal coordinates). Force constants, selectionrules, (F and G matrix if time permits). Applications: Organic molecules, functional groupversus frequency approach, Fermi resonance, frequency shifts because of substitutions, isotope effect., theory and application of Raman Spectroscopy; 4. Other spectroscopic methods like Mass

			Spectrometry, Magnetic Resonance, Photoelectron Spectroscopy. **Course Reference**: 1. Chemical Applications of Group Theory F.A. Cotton; 2. Theory and applications of UV spectroscopy. H.H. Jaffe and M. Orchin; 3. Quantum mechanics, CohenTannoudj, Diu and Lalo (2005); 4. Molecular Spectroscopy I. N. Levine; 5. High Resolution NMR, theory and application, E.D. Becker; 6. Modern Spectroscopy J. M. Hollas.
CHM664A	MODERN PHYSICAL METHODS IN CHEMISTRY	3-0-0-0-9	1. Symmetry and Group Theory: Group multiplication table, elements of a symmetry group,symmetry group classification, characters, group representation, The Great Orthogonality theorem, basis of representation, wave functions as bases of IR representations, symmetry adapted linear combinations, direct products, spectral transitions; 2. Interaction of light with matter, Einsteins coefficients, relationship of Einsteins coefficients with transition moments (no derivation) and transition probabilities, oscillator strength. BeerLambert law, relationship between Einsteins coefficients and total absorbance. Born Oppenheimer approximation, energy levels, potential energy curves, MO and term symbols, Franck Condon principle, symmetry and selection rules, spin and parity forbidden transitions, vibronic interaction; 3. Simple harmonic motion, anharmonicity, introduction of different coordinates (generalised, mass weighted generalized, internal and normal coordinates). Force constants, selection rules, (F and G matrix if time permits). Applications: Organic molecules, functional group versus frequency approach, Fermi resonance, frequency shifts because of substitutions, isotope effect., theory and application of Raman Spectroscopy; 4. Other spectroscopic methods like Mass Spectrometry, Magnetic Resonance, Photoelectron Spectroscopy. **Course Reference**: 1. Chemical Applications of Group Theory F.A. Cotton; 2. Theory and applications of UV spectroscopy. H.H. Jaffe and M. Orchin; 3. Quantum mechanics, CohenTannoudj, Diu and Lalo (2005); 4. Molecular Spectroscopy I. N. Levine; 5. High Resolution NMR, theory and application, E.D. Becker; 6. Modern Spectroscopy J. M. Hollas;
CHM668	ADVANCED MAIN GROUP CHEMISTRY	3-0-0--4	**A**) Topics for Self Study: 1. VSEPR Theory and prediction of molecular geometry, 2. Symmetry. Symmetry elements and symmetry operations. Point groups. Introduction to character tables. Uses of character tables. **B)** Chemistry of Main group Elements Chemistry of boron: Self study: boranes, bonding in boranes, topology of boranes, synthesis and reactivity, Carboranes and metalla carboranes. Lowvalent boron compounds, organoboron compounds and organic synthesis. Use of 11B NMR in structure elucidation of organoboron compounds. Boron containing polymers. Borazine and Boron Nitride Organo lithium compounds. Synthesis, bonding and reactivity. Organo magnesiusm and organo sodium compounds. Chemistry of Aluminum. Aluminum Alkyls. Unusual organometallic compounds of aluminum. Including

			low oxidation state Al compounds and aluminum clusters. Chemistry of Low valent compounds: NHCs and their analogous group 13, 14 and 15 compounds and the recent advances Multiple bonding in main group elements: Compounds involving silicon, phosphorus, bismuthetc. Synthesis, structure and reactivity. Recent literature on multiple bonding modelsamong low valent compounds Inorganic rings and polymers: Siloxanes, Cyclophosphazenes and cyclophosphazanes. Polysilanes and Polyphosphazenes Noble gas compounds Most of the material for this course will be accessed from primary literature viz., Journal articles. Some text books that will be followed are as follows- **Course Reference**: **A)** 1. Inorganic Chemistry Principles of Structure and Reactivity. 4th Edn. Huheey J. E.; Keiter, E.A.; and Keiter, R. L. HarperCollins, NY, 1993; 2. Concepts and Models of Inorganic Chemsitry. 3rd Edn. Douglas, **B)** McDaniel, D.; and Alexander, J. John Wiley, New York. 1993; 3. Chemistry of the Elements. 2nd Edn. Greenwood, N. N.; and Earnshaw, A. Pergamon, Oxford, 1989; 4. Elschenbroich, C.; and Salzer, A.; Organometallics: A Concise Introduction 3rd Edn. 1999; 5. Inorganic and Organometallic Polymers. Chandrasekhar, V. SpringerVerlag, Heidelberg,2005
CHM668A	ADVANCED MAIN GROUP CHEMISTRY	3-0-0-0-9	A. Topics for SelfStudy 1. VSEPR Theory and prediction of molecular geometry 2. Symmetry. Symmetry elements and symmetry operations. Point groups. Introduction to character tables. Uses of character tables.B. Chemistry of Maingroup Elements Chemistry of boron: Selfstudy: boranes, bonding in boranes, topology of boranes, synthesis and reactivity, Carboranes and metalla carboranes. Lowvalent boron compounds, organo boron compounds and organic synthesis. Use of 11B NMR in structure elucidation of organoboron compounds. Boron containing polymers. Borazine and Boron Nitride Organo lithium compounds. Synthesis, bonding and reactivity. Organo magnesiusm and organo sodium compounds. Chemistry of Aluminum. Aluminum Alkyls. Unusual organometallic compounds of aluminum. Including low oxidation state Al compounds and aluminum clusters. Chemistry of Low valent compounds: NHCs and their analogous group 13, 14 and 15 compounds and the recent advances Multiple bonding in main group elements: Compounds involving silicon, phosphorus, bismuthetc. Synthesis, structure and reactivity. Recent literature on multiple bonding models among low valent compounds Inorganic rings and polymers: Siloxanes, Cyclophosphazenes and cyclophosphazanes. Polysilanes and Polyphosphazenes Noble gas compounds Most of the material for this course will be accessed from primary literature viz., Journalarticles. Some text books that will be followed are as follows- **Course Reference**: 1. Inorganic ChemistryPrinciples of Structure and Reactivity. 4th Edn. Huheey J. E.; Keiter, E.A.; and Keiter, R. L. HarperCollins, NY, 1993; 2. Concepts and Models of Inorganic Chemsitry. 3rd Edn. Douglas, B.;

			McDaniel, D.; and Alexander, J. John Wiley, New York. 1993; 3. Chemistry of the Elements. 2nd Edn. Greenwood, N. N.; and Earnshaw, A. Pergamon, Oxford, 1989; 4. Elschenbroich, C.; and Salzer, A.; Organometallics: A Concise Introduction 3rd Edn. 1999; 5. Inorganic and Organometallic Polymers. Chandrasekhar, V. SpringerVerlag, Heidelberg,2005.
CHM679	MOLECULAR REACTION DYNAMICS	3-0-0--4	1. Introduction: Review of kinetic theory of gases, collisions atomic and molecular; 2. Rate theories Transition state theory and RRKM theory, scattering classical and quantum; 3. Reactive Collisions ,Potential energy surfaces, atomdiatom reactions, polyatomic reactions, stateselective,molecular beams, reaction rates and cross sections; 4. Dynamics in gas phase Photodissociation, energy transfer, stereodynamics, chemistry in real time with lasers,control; 5. Dynamics in condensed phase Solvation, diffusion, barrier crossing, Kramer Grote Hynes theory, Langevin equation,correlation functions; 6. Advanced topics Dynamics on surfaces, spatiotemporal aspects of pattern formation, ultrafast dynamics. **Course Reference**: 1. Levine, Molecular Reaction Dynamics, 2005; 2. Henriksen & Hansen, Theories of Molecular Reaction Dynamics, 2008; 3. Schinke, Photodissociation Dynamics, 1993; 4. Manz & Wste, Femtosecond Chemistry, 1995; 5. Nitzan, Chemical Dynamics in Condensed Phases, 2006.
CHM681	BASIC BIOLOGICAL CHEMISTRY	3-0-0--4	Recombinant DNA techniques, Protein folding, design and Engineering, ChouFasman rules, Ramachandran plot and conformation of biopolymers. Mechanisms of important enzymes. Biosynthesis of nucleic acids and proteins. confactors. Immunology. Immune response, Innate immunity and adaptive immunity, Immune dysfunction and its consequences, Immunogenicity, antigens, antibody diversity, monoclonal antibodies, autoimmunity, Hybridoma technology Biosynthesis of lipids and fatty acids. Secondary metabolism, Membrane transport, Aminoacid biosynthesis and metabolism. Cell differenciation, Regulation of gene expression, recombination, DNA replication, signal transduction. Suggested reading: Fundamentals of Biochemistry by Voet, Voet and Pratt, Biochemistry by L. Stryer, Proteins by T.E. Creighton, Genes VII by B. Lewin, Introduction toprotein structure by Branden and Tooze, Enzyme structure and Mechanism by Alan Fersht.
CHM684	COMPUTER PROGRAMMING FOR CHEMISTRY	3-0-0-0-4	Fortran and Computer Programming: Elements of Fortran programming, constants, variablesand operators, control statements, I/O operations, functions and subprograms, common, equivalence, arrays, strings, DATA statements, Disk I/O. New features in Fortran 90 compared to Fortran 77. Programming considerations Round off and truncation errors, pitfalls and debugging (18) Numerical Methods: Roots of equations Bisection and Newton Raphson methods, Systemof linear equations, Gaussian, GaussJordan elimination, Nonlinear system of equations. Regression analysis and Least square fit, Linear, Polynomial and

			NonLinear regression analysis, eigenvalues and eigenvectors, Numerical differentiation and integration, Differential equations. Applications to chemistry: statistical thermodynamics, chemical kinetics, Curve fitting, Gaussian and Lorentzian deconvolution. Use of software packages such as visualization, semiempirical methods. **Course Reference**:1. Michael Boillot, Understanding Fortran77, wess publishing company, New York(1987); 2. Fortran95/2003 for scientists and engineers, S.J.Chapman, McGrawHill (2008); 3. (Ed) D.F. De Tar, Computer programs for chemistry, vol 14, Academic press, New York(1972); 4. K.B. Wiberg, Computer Programming for Chemists, W.A. Benjamin Inc, New York (1965); 5. S.C.Chapra and R.P.Canale, Numerical Methods for Engineers, Tata McGraw Hill, NewDelhi (2003).
CHM684A	COMPUTER PROGRAMMING FOR CHEMISTRY	3-0-0-0-9	Fortran and Computer Programming: Elements of Fortran programming, constants, variables and operators, control statements, I/O operations, functions and subprograms, common, equivalence, arrays, strings, DATA statements, Disk I/O. New features in Fortran 90 compared to Fortran 77. Programming considerations Round off and truncation errors, pitfalls and debugging. Numerical Methods: Roots of equations Bisection and NewtonRaphson methods, Systemof linear equations, Gaussian, Gauss Jordan elimination, Nonlinear system of equations. Regression analysis and Least square fit, Linear, Polynomial and NonLinear regressionanalysis, eigenvalues and eigenvectors, Numerical differentiation and integration, Differential equations Applications to chemistry: statistical thermodynamics, chemical kinetics, Curve fitting, Gaussian and Lorentzian deconvolution. Use of software packages such as visualization, semiempirical methods. **Course Reference**: 1. Michael Boillot, Understanding Fortran77, wess publishing company, New York(1987); 2. Fortran95/2003 for scientists and engineers, S.J.Chapman, McGrawHill (2008); 3. (Ed) D.F. De Tar, Computer programs for chemistry, vol 14, Academic press, New York(1972); 4. K.B. Wiberg, Computer Programming for Chemists, W.A. Benjamin Inc, New York (1965); 5. S.C.Chapra and R.P.Canale, Numerical Methods for Engineers, Tata McGraw Hill, NewDelhi (2003).
CHM685	MOLECULE RADIATION INTERACTION	3-0-0--4	1. Classical Elecromagnetics Fields, Maxwells equations, gauges and optics; 2. Quantization of Electromagnetic Fields Photons, polarizations, Stokes parameters, nontrivial role of the vector potential; 3. Interactions of One and two photon processes, line widths and line shapes, broadening, Raman scattering; 4. Spectroscopy Born Oppenheimer limit, time dependent viewpoints, nonadiabatic effects; 5. Advanced topics Beyond dipole approximation, attosecond spectroscopy. **Course Reference**: 1. Sakurai, Advanced Quantum Mechanics, 1967; 2. CohenTannoudji & DupontRoc, AtomPhoton Interactions, 2004; 3. Landau & Lifshitz, Classical Theory of Fields, 1951; 4. CohenTannoudji,

			DupontRoc & Grynberg, Photons & Atoms, 1989; 5. Feynman Lectures in Physics II, 2005.
CHM685A	MOLECULE RADIATION INTERACTION	3-0-0-0-9	1. Classical Elecromagnetics: Fields, Maxwell's equations, gauges and optics; 2. Quantization of Electromagnetic Fields. Photons, polarizations, Stokes parameters, nontrivial role of the vector potential; 3. Interactions of One and two photon processes, line widths and line shapes, broadening, Raman scattering; 4. Spectroscopy Born Oppenheimer limit, time dependent view points, nonadiabatic effects; 5. Advanced topics; 6. Beyond dipole approximation, attosecond spectroscopy. **Course Reference**:1. Sakurai, Advanced Quantum Mechanics, 1967; 2. Cohen Tannoudji & DupontRoc, Atom Photon Interactions, 2004; 3. Landau & Lifshitz, Classical Theory of Fields, 1951; 4. CohenTannoudji, DupontRoc & Grynberg, Photons & Atoms, 1989; 5. Feynman Lectures in Physics II, 2005.
CHM689	NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY	3-0-0--4	Introduction to NMR Spectroscopy (1) Angular momentum, matrix representation of angular momentum operators. (6) Density matrices, pure and mixed states, density operator and calculation of expectation values (6) Chemical shifts, coupling constants, rotating frame concept and qualitative description ofpulse experiments. 5)Construction of hamiltonian matrix for multispin systems and the solution of AB and ABX spin systems (5) Product operator formalism and vector diagrams (5) Analysis of multipulse experiments: INEPT, DEPT, COSY, NOESY and double quantumfiltered COSY. (12) Multidimensional NMR and macromolecular structure determination. **Course Reference**: 1. M. Goldman, Quantum Description of High-Resolution NMR in Liquids, Clarendon Press, New York (1988). 2. J. A. Pople, W.G. Schneider and H.J. Bernstein, High Resolution NMR, McGraw Hill, NewYork (1959). 3. J Cavanagh, W. J. Fairbrother, A G Palmer III and N.J. Skelton, Protein NMR Spectroscopy, Academic Press (1996). 4. C.P Slichter, Principles of Magnetic Resonance, SpringerVerlag, Berlin (1990).
CHM689A	NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY	3-0-0-0-9	Introduction to NMR Spectroscopy.Angular momentum, matrix representation of angular momentum operators. Density matrices, pure and mixed states, density operator and calculation of expectationvalues. Chemical shifts, coupling constants, rotating frame concept and qualitative description ofpulse experiments. Construction of hamiltonian matrix for multispin systems and the solution of AB and ABX spinsystems. Product operator formalism and vector diagrams. Analysis of multipulse experiments: INEPT, DEPT, COSY, NOESY and double quantumfiltered COSY. Multidimensional NMR and macromolecular structure determination. **Course Reference**: 1. M. Goldman, Quantum Description of High-Resolution NMR in Liquids, Clarendon Press, New York (1988). 2. J. A. Pople, W.G. Schneider and H.J. Bernstein, High Resolution NMR, McGraw Hill, NewYork (1959). 3. J. Cavanagh, W.J. Fairbrother, A.G. Palmer III and N.J. Skelton,

			Protein NMR Spectroscopy, Academic Press (1996). 4. C.P. Slichter, Principles of Magnetic Resonance, SpringerVerlag, Berlin (1990).
CHM691	FRONTIERS IN INORGANIC CHEMISTRY	3-0-0--4	Developing facets of Inorganic Chemistry (2 Lectures) Oxidative generation of molecular oxygen from water during photosynthesis (8 Lectures) Its importance from the standpoint of nonconventional energy research (6 Lectures) Reductive cleavage of the dioxygen bond (3 Lectures) Reductive cleavage of dioxygen bond and novel organic transformations including methane tomethanol performed by a large number of Fe containing metalloenzymes (8 Lectures) Reductive cleavage of dioxygen bond and novel organic transformations performed by alarge number of Cu containing metalloenzymes and synthetic catalysts (15 Lectures) Bioinorganic Chemistry, I. Bertini, H. B. Gray, S. J. Lippard and J. S. Valentine, UniversityScience Books, Mill Valley, 2006.
CHM691A	FRONTIERS IN INORGANIC CHEMISTRY	3-0-0-0-9	Developing facets of Inorganic Chemistry (2 Lectures) Oxidative generation of molecular oxygen from water during photosynthesis (8 Lectures)Its importance from the standpoint of nonconventional energy research (6 Lectures) Reductive cleavage of the dioxygen bond (3 Lectures) Reductive cleavage of dioxygen bond and novel organic transformations including methane tomethanol performed by a large number of Fe containing metalloenzymes (8 Lectures) Reductive cleavage of dioxygen bond and novel organic transformations performed by alarge number of Cu containing metalloenzymes and synthetic catalysts (15 Lectures) **Course Reference**: Bioinorganic Chemistry, I. Bertini, H. B. Gray, S. J. Lippard and J. S. Valentine, University Science Books, Mill Valley, 2006.
CHM693	CHEMICAL APPROACHES TO THE SYNTHESIS OF ADVANCED MATERIALS	3-0-0--4	Chemical methods of synthesis play a crucial role in designing materials, discovering novel materials, metastable phases, nanomaterials and provide less cumbersome routes for the known materials. Chemical ingenuity is important for the synthesis of solid materials with desired structure and properties. Keeping in mind the multidisciplinary nature of the subject, a rational approach to the synthesis of materials is evolved. Indeed, soft chemistry routes/techniques are pursued with greater vigour. These include precursor technique, solgel, hydrothermal, nonaqueous liquid phase reactions, polymer pyrolysis, gas phase reactions, plasma reactions, electron beam evaporation, freeze drying, spray drying, topochemical reactions, intercalation, electrochemical methods, CVDlaser ablation, arcmethod, molten salt method, inter grown structures. Solidstate reactivity, working knowledge of characterization techniques and conventional techniques.
CHM695	MOLECULAR MODELLING IN CHEMISTRY	3-0-0--4	Brief Review of the basic Principles of quantum mechanics of atoms and molecules. Potential energy surfaces and intermolecular interactions: Quantum mechanical ab initiocalculations within Born Oppenheimer approximation and modelling of calculated energies bymodel potentials for

			simple atoms, molecules and ions. Energy calculations using molecular mechanics. Simple applications of molecular modelling: Study of an assembly of atoms or molecules (clusters and/or bulk phases). Approximation of the total potential energy as the sum of pairpotentials. Concept of large number of microstates, averages and basic principles of simulations. Study of cluster and bulk properties through simulations. Modelling of water and small organic molecules: Nonpolarizable and polarizable rigid models. Flexible models and calculation of force constants. Structural, dielectric and dynamical properties of a polar medium: Continuum models versus molecular models. Calculation of free energy using molecular models. Modelling of macromolecules: Study of self organized assemblies, biomolecules like peptides, proteins, membranes and ion channels. Concept of hydrophobic and hydrophilic interactions. Use of molecular modelling in drug design, QSAR. **Course Reference**: 1. A.R. Leach, Molecular Modeling : Principles and Applications, Longman (1996); 2. J. H. Jensen, Molecular Modeling Basics, CRC Press (2010); 3. C. J. Cramer, Essentials of Computational Chemistry: Theories and Models, 2nd Ed., Wiley(2004); 4. J. Israelachvili, Intermolecular and surface Forces, Academic (1991); 5. M. P. Allen and D. J. Tildesley, Computer Simulation of Liquids, Clarendon Press (1987); 6. D. Frenkel and B. Smit, Understanding Molecular Simulation : From algorithms toApplications, Academic Press (1996); 7. P.W. Atkins, Molecular Quantum Mechanics, Oxford (1997); 8. W. Koch & M. C. Holthausen, A Chemists Guide to Density Functional Theory, WileyVCH; 9. A. Szabo, Modern Quantum Chemistry: Introduction to Advanced Electronic StructureTheory, Dover Publications (1996).
CHM695A	MOLECULAR MODELLING IN CHEMISTRY	3-0-0-0-9	Brief Review of the basic Principles of quantum mechanics of atoms and molecules. Potential energy surfaces and intermolecular interactions: Quantum mechanical ab initiocalculations within Born Oppenheimer approximation and modelling of calculated energies bymodel potentials for simple atoms, molecules and ions. Energy calculations using molecular mechanics. Simple applications of molecular modelling: Study of an assembly of atoms or molecules (clusters and/or bulk phases). Approximation of the total potential energy as the sum of pair potentials. Concept of large number of microstates, averages and basic principles of simulations. Study of cluster and bulk properties through simulations. Modelling of water and small organic molecules: Nonpolarizable and polarizable rigid models. Flexible models and calculation of force constants. Structural, dielectric and dynamical properties of a polar medium: Continuum models versus molecular models. Calculation offree energy using molecular models. Modelling of macromolecules: Study of selforganized assemblies, biomolecules like peptides, proteins, membranes and ion channels. Concept of hydrophobic and hydrophilic interactions. Use of molecular modelling in drug design, QSAR.

			Course Reference: 1. A.R. Leach, Molecular Modeling : Principles and Applications, Longman (1996); 2. J. H. Jensen, Molecular Modeling Basics, CRC Press (2010); 3. C. J. Cramer, Essentials of Computational Chemistry: Theories and Models, 2nd Ed., Wiley(2004); 4. J. Israelachvili, Intermolecular and surface Forces, Academic (1991); 5. M. P. Allen and D. J. Tildesley, Computer Simulation of Liquids, Clarendon Press (1987); 6. D. Frenkel and B. Smit, Understanding Molecular Simulation : From algorithms to Applications, Academic Press (1996); 7. P.W. Atkins, Molecular Quantum Mechanics, Oxford (1997); 8. W. Koch & M. C. Holthausen, A Chemists Guide to Density Functional Theory, WileyVCH; 9. A. Szabo, Modern Quantum Chemistry: Introduction to Advanced Electronic StructureTheory, Dover Publications (1996).
CHM696	QUANTUM COMPUTING	3-0-0--4	Thermodynamics of computing, Shannon Theory, elementary information theory (2) Basics of computers, ChurchTuring hypothesis, basics of computing complexity (4) Basic of quantum mechanics, Feynman Block Pseudopolarization Vector Model, Time Dependent Schrodinger equation, basics of approximate quantum approaches (8) Two level Systems, Coherence, Superposition Principle, Density Matrix, Entanglement, Relaxation Processes. Quantum gates and circuits, Theory of Quantum Information and Computation, Deutsch Jozsa algorithm, Shor's algorithm for factoring, Grover's search algorithm and its applications. Quantum Complexity, Quantum Turing Machine. Physical implementations of Quantum Computation, Light polarization, NMR, Cavity QED, Ion Traps, Lasermatter interaction, Coherent Control. **Course Reference**: 1. Michael A. Nielsen and Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, 2000; 2. Jozef Gruska, Quantum Computing, McGraw Hill, 1999; 3. Neil Gershenfeld, Physics of Information Technology, Cambridge University Press, 2000; 4. CohenTannoudji, Diu, and Lalo, Quantum Mechanics I, 2005. 5. Mika Hirvensalo, Quantum Computing, SpringerVerlag New York, 2000. 6. G. Alber, T. Beth, M. Horodecki, P. Horodecki, R. Horodecki, M. Rotteler, H. Weinfurter, R. Werner, A. Zeilinger, Quantum Information: An Introduction to Basic Theoretical Conceptsand Experiments, Springer, 2001.
CHM696A	QUANTUM COMPUTING	3-0-0-0-9	Thermodynamics of computing, Shannon Theory, elementary information theory. Basics of computers, ChurchTuring hypothesis, basics of computing complexity. Basic of quantum mechanics, Feynman Block Pseudopolarization Vector Model, Time Dependent Schrodinger equation, basics of approximate quantum approaches (Two level Systems, Coherence, Superposition Principle, Density Matrix, Entanglement, Relaxation Processes.Quantum gates and circuits, Theory of Quantum Information and Computation, Deutsch Jozsa algorithm, Shor's algorithm for factoring, Grover's search algorithm and its applications. Quantum Complexity, Quantum Turing Machine. Physical

			implementations of Quantum Computation, Light polarization, NMR, Cavity QED, IonTraps, Lasermatter interaction, Coherent Control. a. Michael A. Nielsen and Isaac L. Chuang, Quantum Computation and Quantum Information,Cambridge University Press, 2000; b. Jozef Gruska, Quantum Computing, McGraw Hill, 1999; c. Neil Gershenfeld, Physics of Information Technology, Cambridge University Press, 2000; d. CohenTannoudji, Diu, and Lalo, Quantum Mechanics I, 200; e. Mika Hirvensalo, Quantum Computing, SpringerVerlag New York, 2000; f. G. Alber, T. Beth, M. Horodecki, P. Horodecki, R. Horodecki, M. Rotteler, H. Weinfurter, R.Werner, A. Zeilinger, Quantum Information: An Introduction to Basic Theoretical Conceptsand Experiments, Springer, 2001.
CHM698	CHEMISTRY OF DRUG DESIGN AND METABOLISM	3-0-0--4	Physicochemical Principles of Drug Action; Partition Coefficients; Receptor Effector Theories;Role of Second Messengers in Drug Action; Methods of Receptor Isolation,Characterization and Modeling (5)Principles of Drug Design: Random Screening, Analogue Synthesis, Rational Design,Combinatorial Libraries; Enantiopure Drugs and Regulatory Implications; Theoretical Approaches: QSAR, Topliss Tree, MSA, CoMFA (2)Neuroactive Drugs: Neurons and Neurotransmitters; Brainrelated Disorders andChemotherapy; Drugs Interacting with Cholinergic, Adrenergic, Dopaminergic andHistaminic Receptors and Receptorsubtypes (5)Anticancer, Antimalarial, Antiviral, and Cardiovascular Drugs; Emerging Trends in DrugDesign: Inhibitors of DNA Topoisomerase and Protein Farnesylation & Prenylation; Gene Based Medicines (8) Biopharmaceuticals: Recombinant Proteins as Medicines and Vaccines (2)Drug Delivery: Passive, Assisted and VectorBased Delivery of Conventional and Genetic Drugs; Tissue Specific Delivery of Antitumor Agents (8) Drug Administration, Distribution, Metabolism and Elimination (ADME); Pathways of Drug Metabolism: Enzymology and Molecular Mechanisms; Detoxification of Diverse Drug Classes; Dose Formulation (10)Induction and Inhibition of Drug Metabolism; Toxicological Aspects of Metabolism: MetabolicActivation of Environmental Carcinogens and DNA Damage; Drug Pharmacokinetics andFinal Body Clearance (2) 1. Medicinal Chemistry: A Biochemical Approach, Thomas Nogrady2. Principles of Medicinal Chemistry, William O. Foye3. The Pharmacological Basis of Therapeutics: Goodman and Gilman 4. Introduction to Drug Metabolism, G. Gordon Gibson and Paul Skett
CHM698A	CHEMISTRY OF DRUG DESIGN AND METABOLISM	3-0-0-0-9	Physicochemical Principles of Drug Action; Partition Coefficients; Receptor Effector Theories; Role of Second Messengers in Drug Action; Methods of Receptor Isolation, Characterization and Modeling Principles of Drug Design: Random Screening, Analogue Synthesis, Rational Design, Combinatorial Libraries; Enantiopure Drugs and Regulatory Implications; Theoretical Approaches: QSAR, Topliss Tree, MSA, CoMFA Neuroactive Drugs: Neurons and Neurotransmitters; Brain related Disorders

			andChemotherapy; Drugs Interacting with Cholinergic, Adrenergic, Dopaminergic andHistaminic Receptors and Receptor subtypes. Anticancer, Antimalarial, Antiviral, and Cardiovascular Drugs; Emerging Trends in Drug Design: Inhibitors of DNA Topoisomerase and Protein Farnesylation & Prenylation; Gene Based Medicines Biopharmaceuticals: Recombinant Proteins as Medicines and Vaccines. Drug Delivery: Passive, Assisted and VectorBased Delivery of Conventional and Genetic Drugs; Tissue Specific Delivery of Antitumor Agents (8)Drug Administration, Distribution, Metabolism and Elimination (ADME); Pathways of Drug Metabolism: Enzymology and Molecular Mechanisms; Detoxification of Diverse Drug Classes; Dose Formulation (10)Induction and Inhibition of Drug Metabolism; Toxicological Aspects of Metabolism: Metabolic Activation of Environmental Carcinogens and DNA Damage; Drug Pharmacokinetics and Final Body Clearance. **Course Reference**: 1. Medicinal Chemistry: A Biochemical Approach, Thomas Nogrady; 2. Principles of Medicinal Chemistry, William O. Foye; 3. The Pharmacological Basis of Therapeutics: Goodman and Gilman; 4. Introduction to Drug Metabolism, G. Gordon Gibson and Paul Skett
CHM699	LASERS IN CHEMISTRY AND BIOLOGY	3-0-0-0-4	Fundamentals of Lasers, laser induced fluorescence and multiphoton ionization processes of molecules, probing IVR and dynamics of chemical reactions in liquid and molecular beam, spectroscopy of single molecule, probing of proton dynamics, optical trapping and manipulations of biological macromolecules and organelles, confocal microscopy and fluorescence correlation spectroscopy, applications to diagnostics and biotechnology.
CHM699A	LASERS IN CHEMISTRY AND BIOLOGY	3-0-0-0-9	Fundamentals of Lasers, laser induced fluorescence and multiphoton ionization processes of molecules, probing IVR and dynamics of chemical reactions in liquid and molecular beam, spectroscopy of single molecule, probing of proton dynamics, optical trapping and manipulations of biological macromolecules and organelles, confocal microscopy and fluorescence correlation spectroscopy, applications to diagnostics and biotechnology.
CHM700	PROJECT	0-0-0-0-27	PROJECT
CHM700.	PROJECT	----0	PROJECT
CHM799	RESEARCH	----	Ph. D. Thesis
CHM800	GENERAL SEMINAR2	----0	General Seminar
CHM800A	GENERAL SEMINAR	----0	Graduate Seminar
CHM800B	GENERAL SEMINAR	----0	Graduate Seminar
CHM801	GRADUATE SEMINAR	----0	Graduate Seminar
CHM801A	GRADUATE SEMINAR	----0	Graduate Seminar
CHM801B	GRADUATE	----0	Graduate Seminar

	SEMINAR		
CSO201A	ORGANIC CHEMISTRY: FUNDAMENTALS AND APPLICATIONS	3-1-0-0-11	Basic Organic Chemistry Concepts: introduction to organic molecules and functional groups, understanding organic reactions, stereochemistry and carboncarbon bond forming reactions in organic synthesis. (8 Lectures) Drugs some examples including love drugs and molecules of death. (2 Lectures) Chemistry of odours, dyes and flavors (3 Lectures) Green Chemistry introduction, principles, sustainability, atom economy, some green initiatives, management of resources and its effect on health and environment. Catalysis and biocatalysts in organic chemistry. enantioselectivity and chiral synthesis, organo catalysis (6 Lectures) Enzymes as drug targets and their inhibitors as model inhibitors. (4 Lectures) Solid phase synthesis and strategies for futuristic designs in organic chemistry. Photochemistry: simple concepts and applications (semiconductor photochemistry, solarenergy conversion by photovoltaic cells, photocatalysis, etc.); supramolecular photochemistry. (4Lectures) Organic Materials: polymers (biodegradable polymers, conducting polymers, etc.), smart materials, OLEDs, intelligent gels, dyes, etc Graduate Seminar **Course Reference**:1. Organic Chemistry: Structure, Mechanism,and Synthesis by R. J. Oulettle and J. D. Rawn; 2.Green Organic Chemistry: Strategies, Tools, and Laboratory Experiments by K. Doxsee and J.Hutchinson; 3. Bioorganic Chemisty: A Chemical approach to enzyme action by H. Dugas; 4. Solid Phase organic synthesis: concepts strategies and applications by P. H. Toy and Y. Lam; 5. General Organic Chemistry, Janice Smith, McGrawHill, New York, USA, 2011; 6. Organic Chemistry, W. H. Brown, C. S. Foote, B. L. Iverson and E. V. Anslyn, Brooks/Cole,Belmont, USA, 2012; 7. Principles and Applications of Photochemistry, Brian Wardle, Wiley & Sons, Chichester, UK., 2009; 8. Chemistry of New Materials, FactsOn File, Inc. New York, USA, 2007; 9. Love Drugs, Otto Snow, Thoth Press, USA, 2005; 10. Molecules of Death, R. H. Waring, G. B. Steventon, S. C. Mitchell, Imperial College Press, London, UK, 2007.
CSO202	ATOMS, MOLECULES AND PHOTONS		1. Landmark experiments in physical chemistry; 2. Interplay of theory and experiments in modern physical chemistry; 3. Structure of atoms and molecules; 4. Dynamics of atoms and molecules5. Structure and dynamics of atoms and molecules interacting with radiation. **Course Reference**:1. R. S. Berry, S. A. Rice and J. Ross, Physical Chemistry; 2. D. A. McQuarrie, J. D. Simon, Physical Chemistry: A molecular approach; 3. K. J. Laidler, The World of Physical Chemistry; 4. C. E. Dykstra, Physical Chemistry A modern Introduction

COMPUTER SCIENCE ENGINEERING

COMPUTER SCIENCE & ENGINEERING

B.TECH.								Template No. CSE-1
	SEMESTER							
COURSES	1st	2nd	3rd	4th	5th	6th	7th	8th
	MTH101A [11]	MTH102A [11]	CS201A [09]	ESO207A [12]*	CS330A [12]	CS335A [13]	DE-4 [09]	DE-5 [09]
	PHY103A [11]	PHY102A [11]	CS202A + CS203B [10]	CS220A [12]	CS340A [09]	UGP-2/DE-1/OE-1 (CS396A) [09]	UGP-3/DE-1/OE-1 (CS498A) [09]	OE-4 [09]
	CHM101A [03]	PHY101A [03]	SO/ESO [~10]*	CS251A [06]	CS345A [09]	DE-2 [09]	OE-2 [09]	OE-5 [09]
	ESC101A [14]	LIF101A [06]	ESC201A [14]	SO [11]* (MSO201A)	CS300A [02]	DE-3 [09]	OE-3 [09]	OE-6 [09]
	ENG112A/HSS-1 (Level-1) [11]	CHM102A [08]	COM200A [05]	HSS-2 (Level-1) [11]	CS252A [06]	HSS-3 (Level-2) [09]	HSS-4 (Level-2) [09]	HSS-5 (Level-2) [09]
	PE101A [03]	PE102A [03]	TA201A [06]	TA202A [06]	SO/ESO [~10]*	-	-	UGP-4 [09] (CS499) (extra credits)
	-	TA101A [09]	-	-	UGP-1 [04] (CS395A) (extra credits)	-	-	-
	53	51	54*	58	48/52*	49	45	45/54

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	88	Credits
Department Elective (DE)	:	45	Credits
Open Elective (OE)	:	54	Credits
*SO/ ESO	:	40	Credits
HSS (Level I)	:	22	Credits
HSS (Level II)	:	27	Credits
Total	:	**400**	**Credits**

BASKET – A

CS315A [09]
CS350A [09]
CS360A [09]
CS771A [09]
CS422A [09]
CS425A [09]
CS433A [09]
CS455A [09]

REMARKS:

1) * The 10 credits shown against each ESO/SO in the template are only indicative. ESO/SO courses are available in 6-14 credits each. Students need to ensure that their total ESO/SO credits total up to AT LEAST 40. ESO207A is compulsory for CSE students in the 4th semester.
2) UGP-2 (CS396A) & UGP-3 (CS498A) are optional but if taken, one may be counted as DE and the other as OE.
3) At least 2 DEs must be selected from Basket – A.
4) UGP-1 and UGP-4 (CS395A & CS499A) are optional and do not count towards DE/OE credits.
5) Upto 36 OE credits may be waived from the minimum requirements for students opting for either Dual Degree or Double Major programme.

BT-MT (PG Part – Category – A) *(from the same department)*						Template No. CSE-2
COURSES		SEMESTER				
	1st to 6th	7th	8th	SUMMER	9th	10th
	COURSES SAME AS B.TECH. TEMPLATE	DE PG-1 [09]	DE PG-3 [09]	M.Tech. Thesis [09]	DE PG-6 [09]	M.Tech. Thesis [36]
		DE PG-2 [09]	DE PG-4 [09]	-	M.Tech. Thesis [27]	-
		-	DE PG-5 [09]		-	
			M.Tech. Thesis [09]			
		18	36	09	36	36

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Component	:	54	Credits
Thesis Component	:	81	Credits

REMARKS:

1) Upto 36 OE credits may be used from the BT minimum requirements to fulfil requirements for the BT MT dual degree programme. These will be waived from the BT programme and counted towards PG requirements. All other minimum BT credit requirements need to be fulfilled, including those that are slotted in the 7th and 8th semester of the BT template.

DOUBLE MAJOR		Template No. CSE-3
COURSES		
	Odd Semester	Even Semester
	CS202A + CS203A [10]	CS220A [12]
	CS330A [12]	CS335A [13]
	CS340A [09]	CS251A [06]
	CS345A [09]	CS DE-1 [09]
	CS252A [06]	CS DE-4 [09]
	CS DE-2 [09]	-
	CS DE-3 [09]	
	-	
	64	49*

TOTAL MANDATORY CREDITS FOR SECOND MAJOR IN COMPUTER SCIENCE: 113* CREDITS

REMARKS:

1) Two DEs should be selected from Basket A (Details of Basket A are available in CSE B.Tech. template).
2) Total CSE DE credits should be at least 36.
3) Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.
4) *ESO207 is a compulsory course to be done, but its credits will be counted against the ESO requirement of the first major.

MINOR				Template No. CSE-4
Title	ALGORITHMS	COMPUTER SYSTEMS	THEORY OF COMPUTING	ARTIFICIAL INTELLIGENCE
COURSES	ESO207A [12] *	ESO207A [12] *	ESO207A [12] *	ESO207A [12] *
	CS345A [09]	Any TWO from:	CS340A [09]	CS365A [09]
	Any ONE from: CS645A [09] CS646A [09] CS647A [09] CS648A [09] CS663A [09] CS664A [09] CS719A [09] CS743A [09]	CS220A [12] CS330A [12] CS315A [09] CS335A [12] CS422A [09] CS425A [09] CS433A [09] CS455A [09]	Any ONE from: CS640A [09] CS641A [09] CS642A [09] CS643A [09] CS644A [09] CS649A [09] CS680A [09] CS681A [09] CS687A [09] CS740A [09] CS741A [09] CS742A [09]	Any ONE from: CS671A [09] CS672A [09] CS674A [09] CS675A [09] CS676A [09] CS678A [09] CS679A [09] CS685A [09] CS686A [09] CS771A [09] CS772A [09] CS773A [09] CS774A [09] CS782A [09]

REMARKS:

1) For each Minor stream, the minimum total credit requirement is 30.
2) In each minor stream any related course(s), even if not mentioned in the list of optional courses, may be taken as optional with the permission of the CSE DUGC.
3) *CS210 and ESO207 may be considered equivalent when used as course prerequisite for another course.

DEPARTMENT OF CSE

Courses ID	Course Title	Credits L-T-P-D-[C]	Content
CS201	DISCRETE MATHEMATICS	3-0-0-0-4	Notion of proof: proof by counter example, the contrapositive, proof by contradiction, inductive proofs, Algebra: Motivation of algebraic structures; review of basic group theory with emphasis to finite groups: subgroups and group homomorphism, Lagranges theorem. Commutative rings, ideals, Finite fields and their elementary properties. Some CS applications (e.g., RSA, errorcorrecting codes), Combinatorics: Basic counting techniques, pigeonhole principle, recurrence relations, generating functions, Polyas counting theorem. Basicsof graph theory. Introduction to probabilistic method in combinatorics. Formallogic: Propositional logic: proof system, semantics, completeness, compactness. First order logic: models, proof system, compactness, Examples of formalproofs in, say, number theory or group theory. Some advanced topics. E.g.CS application of logic, introduction to modal and temporal logics, Or, formal number theory including incompleteness theorem.
CS201A	MATHEMATICS FOR COMPUTER SCIENCE -I		1. Mathematical proofs, proofs by induction, by contradiction, proving the contrapositive; 2. Basic counting techniques, pigeonhole principle, recurrence relations, generating functions, principle of inclusionand exclusion, Mobius inversion; 3. Graphs,

			trees definitions. Connectivity, paths, cycles, Eulerian walks, Hamiltonian cycles, cliques, colourings, graph matching, planarity; 4. Discrete probability. Sample space, events, probability basic laws, discrete random variable, expectation, linearityof expectation, independence, conditioning, Bayes theorem, Bernoulli, binomial and geometric distributions, moments and deviations, Markov, Tchebyshef 's inequalities, Chernoff bounds.5. Application of probabilistic methods in combinatorics and graph theory. **Course Reference**: 1. Peter Cameron, Combinatorics: Topics, Techniques, Algorithms, Cambridge University Press, 1995; 2. JH van Lint, RM Wilson, A Course in Combinatorics, 2nd Ed., Cambridge University Press, 2001; 3. David Stirzaker, Elementary Probability, 2nd Ed., Cambridge University Press, 2003; 4. Noga Alan, Joel Spencer, The Probabilistic Method, 3rd Ed., Wiley Interscience, 2008; 5. R Graham, D Knuth, 0 Patashnik, Concrete Mathematics: A Foundation for Computer Science, 2nd Ed.,AddisonWesley, 1994.
CS202A	MATHEMATICS FOR COMPUTER SCIENCE -II		1. Propositional logic syntax and semantics; 2. Tautologies, axiom system and deduction; 3. Proof of soundness and completeness; 4. First order logic syntax and semantics; 5. Structures, models, satisfaction and validity; 6. Axiomatization, soundness and completeness; 7. Optional: some advanced topics. **Course Reference**: 1. HD Ebbinghaus, J Flum, W Thomas, Mathematical Logic, 2nd Ed., Springer Verlag, 1994; 2. HB Enderton, A Mathematical Introduction to Logic, 2nd Ed., Academic Press, 2001; 3. RM Smullyan, First Order Logic, Dover Press, 1995.
CS203B	MATHEMATICS FOR COMPUTER SCIENCE -III	3-0-0-0-5	1. Group theory: definition of groups, cosets and Lagrange's theorem, subgroups, normal subgroups, quotient groups, group action and Burnside's lemma; 2. Rings, Fields, integral domains basic definitions and properties. Field extensions, Chinese remaindering overintegers and polynomial rings. (optional: Introduction to finite fields.) **Course Reference**: 1. IN Herstein, Abstract Algebra, 3rd Ed., Wiley,1996; 2. DS Dummit, RM Foote, Abstract Algebra, John Wiley, 2004.
CS210	DATA STRUCTURES AND AGORITHMS I	3-0-0-0-4	1. Random access machine model, concept of problem size, and asymptotic behaviour of time/space complexity. 2. Estimation of time/space complexity by smooth functions and order notations. 3. A simple example of worstcase time/space complexity analysis.4. Elementary datastructures: arrays, lists, queues, stacks and their applications. 5. Binary search algorithm, binary trees, binary search tree data structure. 6. Balanced binary search tree: RedBlack

			trees. 7. Hashing for insert, search, delete. 8. Heap data structure. 9. Efficient data structures, apart from those in items 6,7, and 8, for sets with the foHowing group of operations:(i) insert, delete, membership, (ii) insert, delete, minimum, (iii) union, intersection, dierence, (iv) disjointset union, 10. Sorting algorithms, including the average case analysis of quicksort.11. Greedy paradigm with examples.12. Divide and conquer paradigm with examples.13. Dynamic programming paradigm with examples.14. Denition of graphs, paths, trees, cycles. Data structures for graphs: adjacency lists, adjacency matrix.15. Graph algorithms: Depth First Search, Breadth First Search, Minimum Spanning Tree.Additional topics based on time and interest may be selected from the following list:16. Single source shortest path computation, topological sorting of a partially ordered set, convex hull computation, string matching algorithms, median computation, distributed algorithms. **Course Reference**: 1. AV Aho, J Hopcroft, JD Ullman, Data Structures and Algorithms, Addison Wesley, 1983; 2. TH Cormen, CF Leiserson, RL Rivest, C Stein, Introduction to Algorithms, 3rd Ed., MIT Press, 2009; 3. AV Aho, J Hopcroft, JD Ullman, The Design and Analysis of Algorithms, AddisonWesley, 1974; 4. MT Goodrich, R Tamassia, DM Mount, Data Structures and Algorithms in Java, 5th Ed., Wiley, 2010.(Equivalent book in C also exists.)
CS210A	DATA STRUCTURES AND ALGORITHMS	3-0-3-0-12	1. Randomaccess machine model, concept of problem size, and asymptotic behaviour of time/space complexity; 2. Estimation of time/space complexity by smooth functions and order notations; 3. A simple example of worstcase time/space complexity analysis; 4. Elementary datastructures: arrays, lists, queues, stacks and their applications; 5. Binary search algorithm, binary trees, binarysearchtree datastructure; 6. Balanced binarysearchtree: RedBlack trees; 7. Hashing for insert, search, delete; 8. Heap data structure; 9. Efficient data structures, apart from those in items 6,7, and 8, for sets with the foHowing group of operations:(i) insert, delete, membership, (ii) insert, delete, minimum, (iii) union, intersection, dierence, (iv) disjointsetunion, 10. Sorting algorithms, including the average case analysis of quicksort.11. Greedy paradigm with examples.12. Divide and conquer paradigm with examples.13. Dynamicprogramming paradigm with examples.14. Denition of graphs, paths, trees, cycles. Data structures for graphs: adjacency lists, adjacency matrix.15. Graph algorithms: Depth First Search, Breadth First Search, Minimum Spanning Tree.Additional topics based on time and interest may be selected from the following list:16. Singlesource

			shortest path computation, topological sorting of a partially ordered set, convex hull computation, string matching algorithms, median computation, distributed algorithms. **Course Reference**: 1. AV Aho, J Hopcroft, JD Ullman, Data Structures and Algorithms, Addison Wesley, 1983; 2. TH Cormen, CF Leiserson, RL Rivest, C Stein, Introduction to Algorithms, 3rd Ed., MIT Press, 2009; 3. AV Aho, J Hopcroft, JD Ullman, The Design and Analysis of Algorithms, AddisonWesley, 1974; 4. MT Goodrich, R Tamassia, DM Mount, Data Structures and Algorithms in Java, 5th Ed., Wiley, 2010.(Equivalent book in C also exists.)
CS220	INTRODUCTION TO COMPUTER ORGANISATION	3-0-2-0-5	Introduction, Overview of basic digital building blocks; truth tables; basic structure of a digital computer, Number representation, Integer unsigned, signed (sign magnitude, 1s complement, 2s complement, rs complement); Characters ASCII coding, other coding schemes; Real numbers fixed and floating point, IEEE754, Assembly language programming for some processor, Basic building blocks for the ALU, Adder, Subtractor, Shifter, Multiplication and division circuits, CPU Subblock, Datapath ALU, registers, CPU buses; Control path microprogramming (only the idea), hardwired, logic; External interface, Memory Subblock, Memory organization; Technology ROM, RAM, EPROM, Flash etc.Cache; Cache coherence protocol for uniprocessor (simple), I/O Subblock,I/O techniques interrupts, polling, DMA; Synchronous vs. Asynchronous I/O; Controllers, Peripherals, Disk drives; Printers impact, dot matrix, inkjet, laser; Plotters; Keyboards; Monitors; Advanced Concepts, Pipelining; Introduction to Advanced Processors.
CS220A	COMPUTER ORGANIZATION	3-0-3-0-12	(a) Digital Design using HDLs. Simple circuit designs: For e.g. Counter, Multiplexer, Arithmetic circuits etc.Design of a Simple Processor: Includes register file, ALU, data paths.(b) FPGA Programming Programming on Xilinx Spartan 3E (or equivalent) FPGA.Handling of Inputs: through slide switches, through push buttons.Handling of Outputs: 7 segment display, LED display, LCD display.The designs developed in Part! can be used to program the FPGA.5(c) Assembly Language Programming Programming in assembly language. The assignments should cover the following concepts: Registers; different type of instructions (load, store, arithmetic, logic, branch); operand addressing modes; memory addressing modes; conditions (codes/flags and conditional branches) stack manipulation; procedurecalls; procedure call conventions (load/store of; arguments on stack, activation records); **Course Reference**: 1. Computer Organization and Design: The Hardware/Software Interface, David A

			Patterson, John L. Hennessy, 4th Edition, Morgan Kaufmann, 2009; 2. Computer Architecture and Organization by William Stallings, PHI Pvt. Ltd., Eastern Economy Edition, Sixth Edition, 2003; 3. Structured Computer Organization by Andrew S Tanenbaum, PHI/Pearson, 4th Edition; 4. Computer Organization by V Carl Hamacher, Zvonks Vranesic, SafeaZaky, McGraw Hill, Vth Edition; 5. Computer System Architecture by M Morris Mano, Prentice Hall of India, 2001; 6. Computer Architecture and Organization by John P Hayes, 3rd Ed. McGraw Hill, 2002; 7. Assembly Language, Online notes, http://linuxassembly.orgj; 8. Books related to HDL (Verilog, VHDL, BSV) programming.
CS251	COMPUTING LABORATORY-I	1-0-3-0-4	1. Basic operating system commands. Students are expected to know the basic shell (e.g., bash) commands and should be able to understand the options and functioning of a command by reading the man and info pages; 2. Editors. Again, students are expected to be familiar with at least one of the two Editors vim and emacs. How ever, they should be able to utilize the multiple features of the editors (such as automatic indentation, ontext sensitive colouring, letype sensitive autowrap, etc.) and not use them simply as a typewriter; 3. Version control. Students will need to completely know how at least one of the version control systems (e.g., cvs, svn, git, dares) work. They should be able to check in, check out, resolve errors and put tags on a snapshot. On all subsequent assignments, they must use a form of version control; 4. Scripting and automation. Of the various types of shells (bash, csh, tcsh, ksh), the preferred choice is bash, although students should be familiar with the different command syntax in other shells as well. Also, they will need to know the various functions (e.g., seq, for) that a shell provides. The choice of the scripting language (per! or python) is open to students; 5. Document preparation. Students will learn using latex for preparing documents. They should also know how to format properly the equations, gures, tables, theorems, etc. using different packages and options. For bibliography management, they should use bibtex, and must use it within the latex documents. For drawing gures and graphs, they can choose to learn some or all of the different softwares used popularly (they include gnu plot, xfig, etc.); 6. Hardware. Students will work handson to learn how to install hard drives, RAM, etc., and in general, assemble a computer from its different parts. **Course Reference**: 1. Manuals; 2. Online help that is available for different tools.
CS251A	COMPUTING LABORATORY-I	1-0-3-0-6	1. Basic operating system commands. Students are expected to know the basic shell (e.g., bash) commands and should be able to understand the

			options and functioning of a command by reading the man and info pages; 2. Editors. Again, students are expected to be familiar with at least one of the two Editors vim and emacs. How ever, they should be able to utilize the multiple features of the editors (such as automatic indentation, ontextsensitive colouring, letype sensitive autowrap, etc.) and not use them simply as a typewriter; 3. Version control. Students will need to completely know how at least one of the version control systems (e.g., cvs, svn, git, dares) work. They_should be able to check in, check out, resolve errors and put tags on a snapshot. On all subsequent assignments, they must use a form of version control; 4. Scripting and automation. Of the various types of shells (bash, csh, tcsh, ksh), the preferred choice is bash, although students should be familiar with the different command syntax in other shells as well. Also, they will need to know the various functions (e.g., seq, for) that a shell provides. The choice of the scripting language (per! or python) is open to students.5. Document preparation. Students will learn using latex for preparing documents. They should also know how to format properly the equations, gures, tables, theorems, etc. using different packages and options. For bibliography management, they should use bibtex, and must use it within the latex documents. For drawing gures and graphs, they can choose to learn some or all of the different softwares used popularly (they includegnuplot, xfig, etc.). 6. Hardware. Students will work handson to learn how to install hard drives, RAM, etc., and in general, assemble a computer from its different parts. **Course Reference**: 1. Manuals.2. Online help that is available for different tools.
CS252	COMPUTING LABORATORY II	1-0-6-0-4	1. System administration: Students will learn to setup and manage a network server including a web server andan email server. They should also be familiar with various network protocols. Further, students will be able to administer different. components of the system by using various monitoring tools. They should also learn simple load balancing tools; 2. Security: While setting up different network and database servers, students will learn to manage the security issues including different attacks. Public key infrastructure (PKI) is a good example of how? to setup, manage, and distribute certicates that are issued as authorization tools. As part of maintaining systerns, students willneed to use system vulnerability and intrusion testing tools as well; 3. Compiler tools: Students will need to learn the various lowlevel tools used routinely in compilers including lexand yacc; 4. Programming environment tools: For efcient programming, students are expected to use various integrated development environments (IDEs) such as

			eclipse and debuggers such as gdb. They should also use tools for effective tagging and browsing of source code. Finally, they will learn to use the build tools that are necessary for large software projects. **Course Reference:** 1. Manuals; 2. Online help that is available for different tools.
CS252A	COMPUTING LABORATORY II	1-0-3-0-6	1. System administration: Students will learn to setup and manage a network server including a web server andan email server. They should also be familiar with various network protocols. Further, students will be able toadminister different. components of the system by using various monitoring tools. They should also learn simple load balancing tools; 2. Security: While setting up different network and database servers, students will learn to manage the security issues including different attacks. Public key infrastructure (PKI) is a good example of how? to setup, manage and distribute certicates that are issued as authorization tools. As part of maintaining sys terns, students willneed to use system vulnerability and intrusion testing tools as well; 3. Compiler tools: Students will need to learn the various lowlevel tools used routinely in compilers including lexand yacc.4. Programming environment tools: For efcient programming, students are expected to use various integrated development environments (IDEs) such as eclipse and debuggers such as gdb. They should also use tools foreffective tagging and browsing of source code. Finally, they will learn to use the build tools that are necessaryfor large software projects. **Course Reference**: 1. Manuals; 2. Online help that is available for different tools.
CS300A	TECHNICAL COMMUNICATION	0-0-2-0-2	TECHNICAL COMMUNICATION
CS315	PRINCIPLES OF DATA BASE SYSTEMS	3-0-0-0-4	Overview of file organisation techniques: sequential, direct, indexed, hashed inverted, Btrees, Data models: relational, network, hierarchical, Relationalmodel: algebra, calculus, normal forms. Implementation of query languages, security and protection of data recovery methods, Concurrent operations ondata bases, introduction to distributed data base systems, case studies. **Course Reference**: 1. H GarciaMolina, JD Ullman and Widom, Database Systems: The Complete Book,2nd Ed., PrenticeHall, 2008; 2. A Silberschatz, H Korth and S Sudarshan, Database System Concepts, 6th Ed., McGrawHill, 2010; 3. R Elmasri, S Navathe, Fundamentals of Database Systems, 6th edition, AddisonWesley, 2010; 4. R Ramakrishnan, J Gehrke, Database Management Systems, 3rd Ed., McGrawHill, 2002.
CS315A	PRINCIPLES OF DATA BASE SYSTEMS	3-0-0-0-9	Overview of file organisation techniques: sequential, direct, indexed, hashed, Inverted, Btrees, Data

			models: relational, network, hierarchical, Relational model: algebra, calculus, normal forms. Implementation of query languages, security and protection of data recovery methods, Concurrent operations ondata bases, introduction to distributed data base systems, case studies. **Course Reference**: 1. H GarciaMolina, JD Ullman and Widom, Database Systems: The Complete Book,2nd Ed., PrenticeHall, 2008; 2. A Silberschatz, H Korth and S Sudarshan, Database System Concepts, 6th Ed., McGrawHill, 2010; 3. R Elmasri, S Navathe, Fundamentals of Database Systems, 6th edition, AddisonWesley, 2010; 4. R Ramakrishnan, J Gehrke, Database Management Systems, 3rd Ed., McGrawHill, 2002.
CS330	OPERATING SYSTEMS	3-0-0-0-4	Introduction: Role of operating System; System Calls; Processes and Threads Concepts of Processes, Threads; Process Control BLock. CPU Scheduling: Examples from contemporary OSes (UNIX and NT). InterProcess Communication MessagePassing, Mailboxes, Pipes; Examples from contemporary OSes (Unix and NT). Process Synchronization Critical Section Problem; Hardware Mechanism for synchronization; Semaphores and Mutex objects; Classical Problems (Producer Consumer, dining philosophers etc.); Monitors; Examples of synchronization mechanisms such as from Java and Pthreads. Deadlocks and Detection,Prevention and avoidance mechanisms.Virtual Memory: Address binding process (compilation and linking); DynamicLinking; Segmentation; Paging Protection; Demand Paging; Page Replacement policies Thrashing, prepaging and other issues; swapping; examples from contemporary OSes (Linux, NT)Files and Directories: File organization in directories; File attributes; Operationson files; Directory attributes and operations on directories; Directory organizations; File and directory protections. File system implementation Concepts of mounting; Allocation mechanisms Contiguous, linked and indexed allocations; Free space management; caching; Examples of files systems from one or more of DOS, BSD, Linux, HPFSand NTFS; Device Drivers: Storage management Disk scheduling; Disk Management; Swapand swap management. Security and Protection Mechanisms: Password based protection; Encryption and Decryption; System Threats Viruses, Wormholes, Trojan Horses etc.
CS330A	OPERATING SYSTEMS	3-0-3-0-12	Introduction: Role of operating System; System Calls; Processes and Threads Concepts of Processes, Threads; Process Control BLock. CPU Scheduling: Examplesfrom contemporary OSes (UNIX and NT). InterProcess Communication Message Passing,

			Mailboxes, Pipes; Examples from contemporary OSes (Unix and NT) Process Synchronization Critical Section Problem; Hardware Mechanism for synchronization; Semaphores and Mutex objects; Classical Problems (Producer Consumer, dining philosophers etc.); Monitors; Examples of synchronization mechanisms such as from Java and Pthreads. Deadlocks and Detection,Prevention and avoidance mechanisms.Virtual Memory: Address binding process (compilation and linking); DynamicLinking; Segmentation; Paging Protection; Demand Paging; Page Replacement policies Thrashing, prepaging and other issues; swapping; examples from contemporary OSes (Linux, NT)Files and Directories: File organization in directories; File attributes; Operationson files; Directory attributes and operations on directories; Directory organizations; File and directory protections.File system implementation Concepts of mounting; Allocation mechanisms Contiguous, linked and indexed allocations; Free space management; caching; Examples of files systems from one or more of DOS, BSD, Linux, HPFSand NTFS;Device Drivers:Storage management Disk scheduling; Disk Management; Swapand swap management.Security and Protection Mechanisms: Password based protection; Encryptionand Decryption; System Threats Viruses, Wormholes, Trojan Horses etc.
CS335	COMPILER DESIGN	3-0-4-0-5	Compiler structure: analysis synthesis model of compilation, various phasesof a compiler, tool- based approach to compiler construction Lexical analysis: interface with input, parser and symbol table, token, lexemeand patterns. Difficulties in lexical analysis. Error reporting. Implementation. Regular definition, Transition diagrams, LEX Syntax analysis: CFGs, ambiguity, associativity, precedence, top down parsing, recursive descent parsing,transformation on the grammars, predictive parsing, bottom up parsing, LRparsers (SLR, LALR, LR), YACC Syntax directed definitions: inherited and synthesized attributes, dependency graph, evaluation order, bottom up and top down evaluation of attributes,L and Sattributed definitions Type checking: type system, type expressions, structural and name equivalence of types, type conversion, overloaded functions and operators, polymorphic functions, type checking in OO languages Run time system: storage organization, activation tree, activation record, parameter passing, symbol table, dynamic storage allocation, garbage collection Intermediate code generation: intermediate representations, translation of declarations, assignments, control flow, boolean expressions and procedure calls. Implementation issuesCode generation and instruction selection: issues, basic

			blocks and flow graphs, register allocation, code generation, DAG representation of programs, codegeneration from DAG, peep hole optimization, code generator generators, specifications of machine Code optimization: Introduction to Code optimization, dataflow analysis.
CS335A	COMPILER DESIGN	3-0-0-3-12	Compiler structure: analysis synthesis model of compilation, various phasesof a compiler, tool- based approach to compiler construction. Lexical analysis: interface with input, parser and symbol table, token, lexemeand patterns. Difficulties in lexical analysis. Error reporting. Implementation.Regular definition, Transition diagrams, LEX Syntax analysis: CFGs, ambiguity,associativity, precedence, top down parsing, recursive descent parsing,transformation on the grammars, predictive parsing, bottom up parsing, LRparsers (SLR, LALR, LR), YACC Syntax directed definitions: inherited and synthesized attributes, dependency graph, evaluation order, bottom up and top down evaluation of attributes,L and Sattributed definitions Type checking: type system, type expressions, structural and name equivalence of types, type conversion, overloaded functions and operators, polymorphic functions, type checking in OO languages Run time system: storage organization, activation tree, activation record,parameter passing, symbol table, dynamic storage allocation, garbage collection Intermediate code generation: intermediate representations, translation ofdeclarations, assignments, control flow, boolean expressions and procedure calls. Implementation issues Code generation and instruction selection: issues, basic blocks and flow graphs, register allocation, code generation, DAG representation of programs, code generation from DAG, peep hole optimization, code generator generators, specifications of machine Code optimization: Introduction to Code optimization, dataflow analysis
CS340	THEORY OF COMPUTATION	3-0-0-0-4	Scope and motivation for theory of computation; informal introduction to computability and complexity; set membership problem as idealization of computing problems; alphabets, strings, languages, automata; deterministic finite automata; nondeterminism; equivalence of DFAs and NFAs; regular expressions and their equivalence with finite automata; pumping lemma; some applications of FAs (e.g., text pattern matching); decision properties of regularlanguages; Myhill Nerode theorem; minimization of DFAs, Grammars as generative devices; context free grammars, derivation, and parse trees; pushdown automata; equivalence with CFGs; normal forms of CFGs, pumping lemma for context free languages; decision and closure properties; some applications (e.g., YACC, markup languages, XML and document

			type definition, etc.),Why considerTuring machines?; basic TM model and its extensions; NDTMs, TM configurations; robustness of TM as a computing model; universal TM, Recursive and relanguages; notion of undecidability; undecidability of halting problem; reducibility; other undecidable problems; Rices theorem; separation of r.e. and recursive languages; existence of non r.e. languages; self reference, recursion theorem; decidability of logical theories; implication to automated theorem proving, Motivation for examining feasibility/infeasibility distinction; definition of time and space complexity classes; P and NP, and their importance; polynomial time reducibility; definition of NP completeness, and NPhardness; CookLevin theorem; some other NPcomplete problems, Brief review of the notion of randomized algorithms; probabilistic TMs; classes RP, BPP, and ZPP; relationships to P and NP; proof of inclusion of BPP in P/poly.
CS340A	THEORY OF COMPUTATION	3-0-0-0-9	Scope and motivation for theory of computation; informal introduction to computability and complexity; set membership problem as idealization of computing problems; alphabets, strings, languages, automata; deterministic finite automata; nondeterminism; equivalence of DFAs and NFAs; regular expressions and their equivalence with finite automata; pumping lemma; some applications of FAs (e.g., text pattern matching); decision properties of regular languages; Myhill Nerode theorem; minimization of DFAs, Grammars as generative devices; context free grammars, derivation, and parse trees; pushdown automata; equivalence with CFGs; normal forms of CFGs, pumping lemma for context free languages; decision and closure properties; some applications (e.g., YACC,markup languages, XML and document type definition, etc.), Why considerTuring machines?; basic TM model and its extensions; NDTMs, TM configurations; robustness of TM as a computing model; universal TM, Recursive and relanguages; notion of undecidability; undecidability of halting problem; reducibility; other undecidable problems; Rices theorem; separation of r.e. and recursive languages; existence of non r.e. languages; self reference, recursion theorem; decidability of logical theories; implication to automated theorem proving, Motivation for examining feasibility/infeasibility distinction; definition of timeand space complexity classes; P and NP, and their importance; polynomial time reducibility; definition of NP completeness, and NP hardness; Cook Levintheorem; some other NP complete problems, Brief review of the notion of randomized algorithms; probabilistic TMs; classes RP, BPP, and ZPP; relationships to P and NP; proof of inclusion of BPP in P/poly.

CS345	ALGORITHMS-II	3-0-2-0-4	Max Flows: Max Flows (Ford Fulkerson and bipartite matching), Linear Algebra: LUP decomposition, inverting matrices, Fast Fourier Transform. Polynomial multiplication, integer multiplication and division, Number Theoretic Algorithms: gcd, modulo arithmetic, Chinese remaindering, RSA, Linear Programming: formulation, simplex, primaldual, Geometric algorithms: convex hull, closest pair, intersection of line segments, polygon triangulation, Randomized Algorithms: identity testing, primality and mincut, Approximation Algorithms: maxcut, tsp, vertex cover etc, Back tracking, Other topics. These may include string matching, parallel algorithms, amortized analysis etc.
CS345A	ALGORITHMS -II	3-0-0-0-9	Max Flows: Max Flows (Ford Fulkerson and bipartite matching), Linear Algebra: LUP decomposition, inverting matrices, Fast Fourier Transform. Polynomial multiplication, integer multiplication and division, Number Theoretic Algorithms: gcd, modulo arithmetic, Chinese remaindering, RSA, Linear Programming: formulation, simplex, primal dual, Geometric algorithms: convex hull, closestpair, intersection of line segments, polygon triangulation, Randomized Algorithms: identity testing, primality and mincut, Approximation Algorithms: maxcut, tsp, vertex cover etc, Back tracking, Other topics. These may include string matching, parallel algorithms, amortized analysis etc.
CS350	PRINCIPLES OF PROGRAMMING LANGAUGES	3-0-0-0-4	Brief history of development of programming languages, Introduction imperative programming, functional programming, logic programming and objectoriented programming, Values and types, Notion of variables, Lifetime of variableslocal, global and heap variables, Bindings and environments, bindables, scopeblock structure, static and dynamic scoping, Abstraction procedural andfunction abstractions, Type systems monomorphic type systems. Introductionto polymorphism, Types of polymorphism overloading, parametric polymorphism, polymorphic types, Type checking and type inference inference rules for monomorphic types, introduction to polymorphic type inference, Functional programming, Logic Programming, Object oriented programming. **Course Reference**: 1. Martn Abadi, Luca Cardelli, A Theory of Objects, Springer 1996; 2. Luca Cardelli, P Wegner, On Understanding Types, Data Abstraction and Polymorphism, ACM ComputingSurveys, 17{4), pp 471, 1985; 3. M Hennessey, The Semantics of Programming Languages, John Wiley, 1990; 4. J. LLoyd, Foundations of Logic Programming, Springer Verlag, 1984; 5. L. C. Paulson, ML for the Working Programmer, 2nd Ed., Cambridge University Press, 1996; 6. Benjamin C. Pierce, Types and programming languages, MIT Press, 2002; 7. C. Reade, Elements

			of Functional Programming, Addison Wesley, 1989; 8. P. van Roy and S. Haridi, Concepts, Techniques and Models of Computer Programming, MIT Press, 2004; 9. Michael L Scott, Programming Language Pregmatics, 3rd Ed., Morgan Kaufmann, 2009.
CS350A	PRINCIPLES OF PROGRAMMING LANGAUGES	3-0-0-0-9	Brief history of development of programming languages, Introduction imperative programming, functional programming, logic programming and objectoriented programming, Values and types, Notion of variables, Lifetime of variables local, global and heap variables, Bindings and environments, bindables, scope blockstructure, static and dynamic scoping, Abstraction procedural andfunction abstractions, Type systems monomorphic type systems. Introduction to polymorphism, Types of polymorphism overloading, parametric polymorphism, polymorphic types, Type checking and type inference inference rules for monomorphic types, introduction to polymorphic type inference, Functional programming, Logic Programming, Object oriented programming.
CS355	PROGRAMMING TOOLS AND TECHNIQUES	1-0-4-0-4	Software management tools, CVS, Scripting tools, GUI programming tools, Language processing tools, Web programming tools.
CS360	INTRODUCTION TO COMPUTER GRAPHICS	3-0-0-0-4	Introduction to Picture Synthesis and Analysis. Conceptual Framework of an Interactive Graphical Simulation System, Graphics hardware. Basic Raster Graphics Algorithms. Introduction to Simple Raster, Graphics Package (SRGP), Graphics Entities. Geometric Transformations. Object hierarchy. Segmentation. Interaction Techniques, Geometric Modeling in 3D. Viewing in 3D. Concept of Synthetic Camera. Dialogue Design. Graphics User Interfaces. Windowing Systems Graphi cal Modeling of Discrete events. Simulation of Discrete EventDisplays. Animation Techniques. Basic Rules for Animation. Graphical Simulationof continuous motion. Role of Virtual Reality in Graphical Simulation.
CS360A	INTRODUCTION TO COMPUTER GRAPHICS	3-0-0-0-9	Introduction to Picture Synthesis and Analysis. Conceptual Framework of anInteractive Graphical Simulation System, Graphics hardware. Basic Raster Graphics Algorithms. Introduction to Simple Raster, Graphics Package (SRGP), Graphics Entities. Geometric Transformations. Object hierarchy. Segmentation.Interaction Techniques, Geometric Modeling in 3D. Viewing in 3D. Concept of Synthetic Camera. Dialogue Design. Graphics User Interfaces. Windowing Systems Graphi cal Modeling of Discrete events. Simulation of Discrete Event Displays. Animation Techniques. Basic Rules for Animation. Graphical Simulationof continuous motion. Role of Virtual Reality in Graphical Simulation.
CS365	ARTIFICIAL INTELLIGENCE	3-0-0--4	Introduction to AI. Agents and environments. Problem solving by search; uninformed search, informed

	PROGRAMMING		search, constrained satisfaction problems, adversarial search, Knowledge representation and reasoning; rule-based representations, logical formalisms, frames or objectoriented systems, network-based approaches and mixed representations. Theorem proving. Knowledge bases and expert systems. Overview of LISP and PROLOG. Reasoning in uncertain environments. Planning communication and multiagent systems. Learning Vision, NLP. **Course Reference**: 1. Stuart Russell, Peter Norvig, Artificial Intelligence: A Modern Approach, 3rd Ed., Prentice Hall, 2009. Can alsouse 2nd Ed., Pearson Education International, 2003; 2. Nils Nilsson, Artificial Intelligence: A New Synthesis, Morgan Kaufmann, 1998; 3. David Poole, Alan Mackworth, Artificial Intelligence: Foundations for Computational Agents, Cambridge Univ.Press, 2010.
CS365A	ARTIFICIAL INTELLIGENCE PROGRAMMING	3-0-0-0-9	Introduction to AI. Agents and environments. Problem solving by search; uninformed search, informed search, constrained satisfaction problems, adversarial search, Knowledge representation and reasoning; rulebased representations, logical formalisms, frames or object-oriented systems, network-based approaches and mixed representations. Theorem proving. Knowledge bases and expert systems. Overview of LISP and PROLOG. Reasoning in uncertain environments. Planning communication and multiagent systems. Learning Vision, NLP. **Course Reference**: 1. Stuart Russell, Peter Norvig, Artificial Intelligence: A Modern Approach, 3rd Ed., Prentice Hall, 2009; Can alsouse 2nd Ed., Pearson Education International, 2003; 2. Nils Nilsson, Artificial Intelligence: A New Synthesis, Morgan Kaufmann, 1998; 3. David Poole, Alan Mackworth, Artificial Intelligence: Foundations for Computational Agents, Cambridge Univ.Press, 2010.
CS395A	UG PROJECT (UGP-I)	0-0-0-0-4	UG PROJECT (UGPI)
CS396A	UG PROJECT (UGP-II)	0-0-0-0-9	UG PROJECT (UGPII)
CS397	SPECIAL TOPICS IN COMPUTER SCIENCE	0--4	This course is meant for a 3rd year BTech (CSE) student to study a topic of their interest, some what independently. A student may also carry out aproject in this course. In this course, there will be a faculty member associated with each student whose responsibility will be to suggest reading material, hold discussion sessions, monitor the progress of the student, examine the student, and give a grade at the end of the semester.
CS422	COMPUTER ARCHITECTURE	3-0-0-0-4	Introduction: Overview of Computer Architecture, Performance evaluation of processors, Pipelining, Superpipelines, Advanced pipelines, static and dynamic scheduling, Instruction level parallelism, loop unrolling, VLIW and Super scalar processors, Vector

			processing and array processing, Memory: bandwidth issues,memory organization, cache coherence, Symmetric multiprocessors (SMP),NUMAMPs, Massively parallel processors, Cache coherence protocols, Interconnection networks, I/O processing, parallel programming, Examples of contemporary architectures, AS (Reliability, Availability, Scalability) features. **Course Reference**: 1. JL Hennessy, DA Patterson, Computer Architecture: A Quantitative Approach, 4th Ed., Morgan Kaufmann/ElsevierIndia, 2006.
CS422A	COMPUTER ARCHITECTURE	3-0-0-0-9	Introduction: Overview of Computer Architecture, Performance evaluation of processors, Pipelining, Superpipelines, Advanced pipelines, static and dynamic scheduling, Instruction level parallelism, loop unrolling, VLIW and Super scalar processors, Vector processing and array processing, Memory: bandwidth issues,memory organization, cache coherence, Symmetric multiprocessors (SMP),NUMAMPs, Massively parallel processors, Cache coherence protocols, Interconnection networks, I/O processing, parallel programming, Examples of contemporary architectures, AS (Reliability, Availability, Scalability) features. **Course Reference**: 1. JL Hennessy, DA Patterson, Computer Architecture: A Quantitative Approach, 4th Ed., Morgan Kaufmann/ElsevierIndia, 2006.
CS425	COMPUTER NETWORKS	3-0-0-0-4	Introduction: Advantages of computer networks, LAN vs. WAN, ISO/OSI sevenlayer architecture, networks topologies, Physical Layer: transmission media, data encoding, Data Link Layer: Framing, Error detection and correction, Stop and wait protocol, Sliding window protocols, MAC Layer: Aloha protocols, CSMA/CD; Ethernet. Other examples of MAC protocols, Network Layer: Internet working Tunneling, Encapsulation, Fragmentation. Internet Protocol (IP)Header structure, addresses, options, etc. Routing Algorithms and Routing protocols. Other related protocols, for example, ICMP, ARP, RARP, BOOTP, DHCP, Transport Layer: Transmission Control Protocol header, services, connection management, congestion control, sliding window, timers. User Datagram Protocol.Domain Name Service, Unix network programming, socket abstraction. Clientserver architecture, Session, Presentation, Application Layers. Example protocols: Email (SMTP), Telnet, FTP, etc. **Course Reference**: 1. AS Tanenbaum, DJ Wetherall, Computer Networks, 5th Ed., PrenticeHall, 2010; 2. LL Peterson, BS Davie, Computer Networks: A Systems Approach, 5th Ed., Morgan Kauffman, 2011; 3. JF Kurose, KW Ross, Computer Networking: A Top Down Approach, 5th Ed., Addison Wesley, 2009; 4. W Stallings, Cryptography and Network Security,

			Principles and Practice, 5th Ed., PrenticeHall, 2010
CS425A	COMPUTER NETWORKS	3-0-0-0-9	Introduction: Advantages of computer networks, LAN vs. WAN, ISO/OSI seven layer architecture, networks topologies, Physical Layer: transmission media, data encoding, Data Link Layer: Framing, Error detection and correction, Stop and wait protocol, Sliding window protocols, MAC Layer: Aloha protocols, CSMA/CD; Ethernet. Other examples of MAC protocols, Network Layer: Internetworking Tunneling, Encapsulation, Fragmentation. Internet Protocol (IP)Header structure, addresses, options, etc. Routing Algorithms and Routing protocols. Other related protocols, for example, ICMP, ARP, RARP, BOOTP, DHCP, Transport Layer: Transmission Control Protocol header, services, connection management, congestion control, sliding window, timers. User Datagram Protocol.Domain Name Service, Unix network programming, socket abstraction. Clientserver architecture, Session, Presentation, Application Layers. Example protocols: Email (SMTP), Telnet, FTP, etc. **Course Reference:** 1. AS Tanenbaum, DJ Wetherall, Computer Networks, 5th Ed., PrenticeHall, 2010; 2. LL Peterson, BS Davie, Computer Networks: A Systems Approach, 5th Ed., Morgan Kauffman, 2011; 3. JF Kurose, KW Ross, Computer Networking: A TopDown Approach, 5th Ed., AddisonWesley, 2009; 4. W Stallings, Cryptography and Network Security, Principles and Practice, 5th Ed., PrenticeHall, 2010
CS433	PARALLEL PROGRAMMING	3-0-0-0-4	1. Introduction: Why parallel computing; Ubiquity of parallel hardware/multicores; Processes and threads; Programming models: shared memory and message passing; Speedup and efciency; Amdahls Law; 2. Introduction to parallel hardware: Multicores and multiprocessors; shared memory and message passing architectures; cache hierarchy and coherence; sequential consistency; 3. Introduction to parallel software: Steps involved in developing a parallel program; Depen dence analysis; Domain decorriposition; Task assignment: static and dynamic; Performance issues: 4C cache misses, inherent and artifactual communiication, false sharing, computation to communication ratio as a guiding metric for decomposition,hot spots and staggered communication.4. Shared memory parallel programming: Synchronization: Locks and barriers; Hardware primitives for efcient lock implementation; Lock al gorithms; Relaxed consistency models; Highlevel language memory models (such Java and/or C++); Memory fences. Developing parallel programs with UNIX fork model: PC with shared memory and message pass ing; UNIX semaphore and its aliornone semantic. Example case studies (see note below for some details). Developing parallel

			programs with POSIX thread library: Thread creation; Thread join; Mutex; Condition variables. Example case studies (see note below for some details). Developing parallel programs with Open MP directives: Parallel for; Parallel section; Static, dy namic, guided, and runtime scheduling; Critical sections and atomic operations; Barriers; Reduction. Example case studies (see note below for some details).5. Message passing programming: Distributed memory model; Introduction to message passing interface (MPI); Synchronization as Send/Recv pair; Synchronous and asynchronous SendfRecv; Collective communication: Reduce, Broadcast, Data distribution, Scatter, Gather; MPI derived data types. Example case studies (see note below for some details). Notes:1. The example case studies should be chosen to cover a wide variety of parallel algorithms drawn from nu meric aswell as nonnumeric domains. Possibilities include parallel sort, parallel prex, parallel search, graph algorithms, parallel ranking, reduction, algorithms using tree, fan, pipe paradigms, matrix computa tion, equation solvers, nbody simulation, ray tracing, etc.2. The instruction must accompany an adequate number of programming assignments demonstrating the concepts.3. The instructors are encouraged to offer large semesterlong programming projects.
CS433A	PARALLEL PROGRAMMING	3-0-0-0-9	1. Introduction: Why parallel computing; Ubiquity of parallel hardware/multicores; Processes and threads; Programming models: shared memory and message passing; Speedup and efciency; Amdahls Law; 2. Introduction to parallel hardware: Multicores and multiprocessors; shared memory and message passing architectures; cache hierarchy and coherence; sequential consistency; 3. Introduction to parallel software: Steps involved in developing a parallel program; Depen dence analysis; Domain decorriposition; Task assignment: static and dynamic; Performance issues: 4C cache misses, inherent and artifactual communication, false sharing, computation to communication ratio as a guiding metric for decomposition,hot spots and staggered communication.4. Shared memory parallel programming: Synchronization: Locks and barriers; Hardware primitives for efcient lock implementation; Lock al gorithms; Relaxed consistency models; Highlevel language memory models (such Java and/or C++); Memory fences. Developing parallel programs with UNIX fork model: PC with shared memory and message pass ing; UNIX semaphore and its aliornone semantic. Example case studies (see note below for some details). Developing parallel programs with POSIX thread library: Thread creation; Thread join; Mutex; Condition variables. Example

			case studies (see note below for some details). Developing parallel programs with Open MP directives: Parallel for; Parallel section; Static, dy namic, guided, and runtime scheduling; Critical sections and atomic operations; Barriers; Reduction. Example case studies (see note below for some details).5. Message passing programming: Distributed memory model; Introduction to message passing interface (MPI); Synchronization as Send/Recv pair; Synchronous and asynchronous SendfRecv; Collective communication: Reduce, Broadcast, Data distribution, Scatter, Gather; MPI derived data types. Example case studies (see note below for some details). Notes:1. The example case studies should be chosen to cover a wide variety of parallel algorithms drawn from nu meric aswell as nonnumeric domains. Possibilities include parallel sort, parallel prex, parallel search, graph algorithms, parallel ranking, reduction, algorithms using tree, fan, pipe paradigms, matrix computa tion, equation solvers, nbody simulation, ray tracing, etc.2. The instruction must accompany an adequate number of programming assignments demonstrating the concepts.3. The instructors are encouraged to offer large semester long programming projects.
CS455	INTRODUCTION TO SOFTWARE ENGINEERING	3-0-0-0-4	Introduction industrial strength software, problem of software development, problem of scale, basic process-based approach, etc. Software Process Models concept of processes, ETVX model for process specification, different process models and when they are useful, Requirement analysis and specification the basic problem, the sub phases in the phase, analysis techniques (structured analysis), specification, validation, function point analysis, Project planning effort, schedule, quality, project monitoring, and basic CM, Design principles and structured design methodology partitioning, top down and bottomup,stepwise refinement, coupling and cohesion, Coding style, structured programming, verification concepts. Testing testing purpose, levels of testing, black box testing, white box testing, different test case generation approaches, Other topics object oriented, metrics, standards, industrial practices. 1. Ian Somerville, Software Engineering, 9th Ed., Pearson, 2010; 2. C Ghezzi, M Jazayeri, D Mandrioli, Fundamentals of Software Engineering, 2nd Ed., PrenticeHall, 2002; 3. RN Taylor, N Medvidovic, EM Dashofy, Software Architecture: Foundations, Theory and Practice, John Wiley,2009; 4. R Jhala, R Majumdar, Software Model Checking, ACM Computing Surveys, 41(4), Article 21, 2009; 5. AV Aho, MS Lam, R Sethi, JD Ullman, Compiler Design: Principles, Techniques and Tools, 2nd Ed., PrenticeHall,2006

CS455A	INTRODUCTION TO SOFTWARE ENGINEERING	3-0-0-0-9	Introduction industrial strength software, problem of software development, problem of scale, basic processbased approach, etc. Software Process Models concept of processes, ETVX model for process specification, different process models and when they are useful, Requirement analysis and specification the basic problem, the sub phases in the phase, analysis techniques (structured analysis), specification, validation, function point analysis, Project planning effort, schedule, quality, project monitoring, and basic CM, Design principles and structured design methodology partitioning, top down and bottomup,stepwise refinement, coupling and cohesion, Coding style, structured programming, verification concepts. Testing testing purpose, levels of testing, black box testing, white box testing, different test case generation approaches, Other topics object oriented, metrics, standards, industrial practices. **Course Reference**: 1. Ian Somerville, Software Engineering, 9th Ed., Pearson, 2010; 2. C Ghezzi, M Jazayeri, D Mandrioli, FUndamentals of Software Engineering, 2nd Ed., PrenticeHall, 2002; 3. RN Taylor, N Medvidovic, EM Dashofy, Software Architecture: Foundations, Theory and Practice, John Wiley,2009; 4. R Jhala, R Majumdar, Software Model Checking, ACM Computing Surveys, 41(4), Article 21, 2009; 5. AV Aho, MS Lam, R Sethi, JD Ullman, Compiler Design: Principles, Techniques and Tools, 2nd Ed., PrenticeHall,2006
CS498	B TECH PROJECT	0-0-12-0-4	B TECH PROJECT
CS498A	UNDER GRADUATE PROJECT-III	0-0-0--9	UG PROJECT (UGPIII)
CS499	B TECH PROJECT	0-0-12-0-4	B TECH PROJECT
CS499.	B. TECH PROJECT		B TECH PROJECT
CS601	MATHEMATICS FOR COMPUTER SCIENCE	3-0-0-0-4	Programming utilities, lab exercise for developing large system and application programs.
CS601A	MATHEMATICS FOR COMPUTER SCIENCE	3-0-0-0-9	Programming utilities, lab exercise for developing large system and application programs.
CS602	DESIGN AND ANALYSIS OF ALGORITHMS	3-0-0-0-4	Basic concepts of operating systems, compilers, and data base management systems.
CS602A	DESIGN AND ANALYSIS OF ALGORITHMS	3-0-0-0-9	Basic concepts of operating systems, compilers, and data base management systems.
CS618	INDEXING AND SEARCHING TECHNIQUES IN DATABASE	3-0-0-0-4	Index structures Rtree, Mtree, VAfile, etc., Space partitioning versus data partitioning methods; Similarity queries Range search, kNN search, Selfjoin; Retrieval techniques Fagin's Algorithm, Threshold Algorithm, Probabilistic Fagin's; Vector Space embedding, properties; Dimensionality reduction SVD,PCA, FastMap, Wavelets, Fourier transform, etc.; Distance measures Lpnorm, Mahalanobis

			distance, Kullback Leibler divergence measure, Earth Mover's Distance, etc.; Data compression Wavelets, Fourier, Voptimal histograms;
CS618A	INDEXING AND SEARCHING TECHNIQUES IN DATABASE	3-0-0-0-9	Index structures Rtree, Mtree, VAfile, etc., Space partitioning versus data partitioning methods; Similarity queries Range search, kNN search, Selfjoin; Retrieval techniques Fagin's Algorithm, Threshold Algorithm, ProbabilisticFagin's; Vector Space embedding, properties; Dimensionality reduction SVD,PCA, FastMap, Wavelets, Fourier transform, etc.; Distance measures Lpnorm, Mahalanobis distance, Kullback Leibler divergence measure, Earth Mover's Distance, etc.; Data compression Wavelets, Fourier, Voptimal histograms;
CS622	ADVANCED COMPUTER ARCHITECTURE	3-0-0--4	Single threaded execution, traditional microprocessors, DLP, ILP, TLP, memory wall, Parallel programming and performance issues, Shared memory multiprocessors, Synchronization, smallscale symmetric multiprocessors on asnoopy bus, cache coherence on snoopy buses, Scalable multiprocessors, Directory based cache coherence, Interconnection network, Memory consistency models, Software distributed shared memory, multi threading in hardware, Chip multiprocessing, Current research and future trends.
CS624	TOPICS IN EMBEDED SYSTEMS	3-0-0--4	Current topics in the design, specifications and analysis of embedded systems. Contemporary topics such as specifications of embedded systems, analysis of embedded systems, interface to the realtime operating systems, design case studies, design methodologies, etc. Other topics may include verification of embedded systems like formal verification, cosimulation, etc., estimation of hardware and software costs, partitioning, synthesis (hardware, software, memory, bus), retargetable usage of the software, specification and verification of the OS schedules, hard and soft realtime operating systems, and fault tolerant systems.
CS625	ADVANCED COMPUTER NETWORKS	3-0-0--4	Introduction: Overview of computer networks, sevenlayer architecture, TCP/IP suite of protocols, etc. MAC protocols for highspeed LANs, MANs, and wireless LANs. (for example, FDDI, DQDB, HIPPI, Gigabit Ethernet, Wireless ethernet, etc.) Fast access technologies. (For example, ADSL, Cable Modem, etc.) ATM Networks. ATM layer. ATM Adaptation Layers. Congestion Control. Signalling Routing, QoS support, Neighbour disconery, Auto configuration. Changes to other protocols. Application Programming Interface for IPv6. Mobility in networks. Mobile IP. Security related issues. IP Multicasting. Multicast routing protocols, adderss assignments, session discovery, etc. TCP extensions for highspeed networks, transaction-oriented applications. Other

			new optionsin TCP. Network security at various layers. Secure HTTP, SSL, ESP, Authentication header, Key distribution protocols. Digital signatures, digital certificates.
CS625A	ADVANCED COMPUTER NETWORKS	3-0-0-0-9	Introduction: Overview of computer networks, sevenlayer architecture, TCP/IP suite of protocols, etc. MAC protocols for high speed LANs, MANs, andwireless LANs. (for example, FDDI, DQDB, HIPPI, Gigabit Ethernet, Wireless ethernet, etc.) Fast access technologies. (For example, ADSL, Cable Modem, etc.) ATM Networks. ATM layer. ATM Adaptation Layers. Congestion control. Signalling, Routing, QoS support, Neighbour disconery, Auto configuration. Changes to other protocols. Application Programming Interface for IPv6. Mobility in networks. Mobile IP. Security related issues. IP Multicasting. Multicast routing protocols, adderss assignments, session discovery, etc. TCP extensions for highspeed networks, transaction-oriented applications. Other new optionsin TCP. Network security at various layers. Secure HTTP, SSL, ESP, Authentication header, Key distribution protocols. Digital signatures, digital certificates.
CS628	COMPUTER SYSTEMS SECURITY	3-0-0--4	Introduction: need and basic goals for computer security, security threats etc. Cryptographic building blocks: Symmetric and asymmetric key cryptography, cryptographic hash functions, digital signature schemes etc., with representative applications for each. Operating System Security: Lowlevel protection mechanisms, access control: models for access control, some confidentiality, integrity, and hybrid models of access control such as BellLa Padula, Biba, Chinese Wall etc., discretionary v/s mandatory access control. Case studies: Java access control policy specifications, SELinux security modeland implementation. Program flaws: Bugs which have security implications such as buffer overflows, race conditions etc. Malicious code: Viruses, worms, Trojan horses; how they work and how to defend against them. Network Security: problems in network security; kinds of attacks, PKI, keyexchange protocols, example protocols such as PGP, Kerberos, IPSEC/ VPN, SSL, S/MIME etc. Protocol vulnerabilities: examples of protocol vulnerabilitiessuch as in TCP/IP, denial of service attacks etc. Tools for network security such as firewalls and intrusion detection systems.
CS628A	COMPUTER SYSTEMS SECURITY	3-0-0-0-9	Introduction: need and basic goals for computer security, security threats etc. Cryptographic building blocks: Symmetric and asymmetric key cryptography, cryptographic hash functions, digital signature schemes etc., with representative applications for each. Operating System Security: Lowlevel protection mechanisms, access control: models for access

			control, some confidentiality, integrity, and hybrid models of access control such as BellLa Padula, Biba, Chinese Wall etc., discretionary v/s mandatory access control. Case studies: Java access control policy specifications, SELinux security model and implementation. Program flaws: Bugs which have security implications such as buffer overflows, race conditions etc. Malicious code: Viruses, worms, Trojan horses; how they work and how to defend against them. Network Security: problems in network security; kinds of attacks, PKI, keyexchange protocols, example protocols such as PGP, Kerberos, IPSEC/VPN, SSL, S/MIME etc. Protocol vulnerabilities: examples of protocol vulnerabilitiessuch as in TCP/IP, denial of service attacks etc. Tools for network security such as firewalls and intrusion detection systems.
CS632	TOPICS IN DISTRIBUTED SYSTEMS	3-0-0--4	Local area networks, concurrency control and recovery, distributed languages and communication primitives, file servers, case studies of distributed systems.
CS632A	TOPICS IN DISTRIBUTED SYSTEMS	3-0-0-0-9	Local area networks, concurrency control and recovery, distributed languages and communication primitives, file servers, case studies of distributed systems.
CS633	PARALLEL COMPUTING	3----4	Introduction: Paradigms of parallel computing: Synchronous vector/array, SIMD, Systolic; Asynchronous MIMD, reduction paradigm. Hardware taxonomy: Flynns classifications, Handlers classifications. Software taxonomy: Kungs taxonomy, SPMD. Abstract parallel computational models: Combinational circuits, Sorting network, PRAM models, Interconnection RAMs. Parallelism approaches data parallelism, control parallelism. Performance Metrics: Laws governing performance measurements. Metrics speedups, efficiency, utilization, communication overheads, single/multiple program performances, bench marks. Parallel Processors: Taxonomy and topology shared memory mutliprocessors, distributed memory networks. Processor organization Static and dynamic interconnections. Embeddings and simulations. Parallel Programming: Shared memory programming, distributed memory programming, object-oriented programming, data parallel programming, functional and dataflow programming. Scheduling and Parallelization: Scheduling parallel programs. Loop scheduling. Parallelization of sequential programs. Parallel programming support environments.
CS634	MOBILE COMPUTING	3-0-0-0-4	Introduction: Mobile computing a vision for future, ubiquitous computing versus virtual reality, software models for mobile computing. Data management Issues. Distributed algorithms and mobility: structuring

			distributed algorithms for mobile computing environments, token ring algorithm. Publishing and accessing data in the air: pull and push based data transfers, data dissemination by broadcast, treating air as cache, energy efficient indexing in air. Handoff management: hand off detection, failures, channel assignments. Location Management: twotier HLRVLR scheme, mobile IP, hierarchical tree- based scheme, regional directories, distributed location management. Approximate query processing: concept hierarchy, summary database, updates and view maintenance, approximate query processing. Mobile Transaction Models. Mobile Computing: technological prospective: 1G, 2G and 3G network and services, the Internet, mobile computing and cellular telephony, voice and data serviceson 3G networks, battery problem and power dissipation, low energy processors. File system support for mobile computing: Coda and Bayou file systems. Adhoc network routing protocols: DSDV, GSR, FSR, DSR, AODV.
CS634A	MOBILE COMPUTING		Introduction: Mobile computing a vision for future, ubiquitous computing versus virtual reality, software models for mobile computing. Data management Issues. Distributed algorithms and mobility: structuring distributed algorithms for mobile computing environments, token ring algorithm. Publishing and accessing data in the air: pull and push based data transfers, data dissemination by broadcast, treating air as cache, energy efficient indexing in air. Handoff management: handoff detection, failures, channel assignments. Location Management: twotier HLRVLR scheme, mobile IP, hierarchical tree-based scheme, regional directories, distributed location management. Approximate query processing: concept hierarchy, summary database, updates and view maintenance, approximate query processing. Mobile Transaction Models. Mobile Computing: technological prospective: 1G, 2G and 3G network and services, the Internet, mobile computing and cellular telephony, voice and data serviceson 3G networks, battery problem and power dissipation, low energy processors File system support for mobile computing: Coda and Bayou file systems. Adhoc network routing protocols: DSDV, GSR, FSR, DSR, AODV.
CS636A	ANALYSIS OF CONCURRENT PROGRAMS		Programing language Basics: Syntax, Semantics,Type Review of concurrent programming paradigms:shared memory message passing, partitioned global address space, Synchronizations primitives:locks monitors, semaphores, barriers, flags, conditions variables, Concurrency bogs: race conditions, data races, atomicity violations, order violations, deadlocks, livelocks, Consistency models: strict consistency, sequential consistency, linearizability (atomic consistency),relaxed memory

			models,memory fences to enforce orderings.Dataflow analysis for concurrent programs, Deductive Verifications: Hoare Logic, owickiGries, Rely Guarantee, Concurrent separations Logic, Statespace reductions techniques: Formal modelling of concurrent systems, Mazurkiewicz traces, Logic
CS639	PROGRAM ANALYSIS, VERIFICATION AND TESTING	3-0-0-0-4	Data flow Analysis; Inter procedural Analysis: functional, call string and graph reachability -based approaches Abstract Interpretation; Weakest Precondition, Floyd Hoare Logic, Separation Logic; Software Model Checking: symbolic execution, state space reduction, state less model checking, counter example guided abstraction refinement, model checking of concurrent programs, Program Testing: program testing basics, automatic test case generation, directed testing. 1. Edsger Wybe Dijkstra. A Discipline of Programming. Prentice Hall PTR, Upper Saddle River, NJ, USA, 1997; 2. David Gries. The Science of Programming. SpringerVerlag New York, Inc., Secaucus, NJ, USA, 1987; 3. S. S. Muchnick and N. D. Jones, editors. Program Flow Analysis: Theory and Applications. PrenticeHall: Englewood Cliffs, NJ, 1981; 4. Flemming Nielson, Hanne R. Nielson, and Chris Hankin. Principles of Program Analysis. SpringerVerlag New York, Inc., Secaucus, NJ, USA, 1999; 5. Alfred V. Aho, Monica S. Lam, Ravi Sethi, and Jeffrey D. Ullman. Compilers: Principles, Techniques, and Tools (2nd Edition). AddisonWesley Longman Publishing Co., Inc., Boston, MA, USA, 2006; 6. Michael Huth and Mark Ryan. Logic in Computer Science: Modelling and Reasoning about Systems. Cambridge University Press, New York, NY, USA, 2004; 7. Edmund M. Clarke, Jr., Orna Grumberg, and Doron A. Peled. Model checking. MIT Press, Cambridge, MA, USA, 1999.
CS639A	PROGRAM ANALYSIS, VERIFICATION AND TESTING	3-0-0-0-9	Data flow Analysis; Interprocedural Analysis: functional, call string and graph reachability-based approaches Abstract Interpretation; Weakest Precondition, Floyd Hoare Logic, Separation Logic; Software Model Checking: symbolic execution, state space reduction, state less model checking, counter example guided abstraction refinement, model checking of concurrent programs, Program Testing: program testing basics, automatic test case generation, directed testing. **Course Reference**: 1. Edsger Wybe Dijkstra. A Discipline of Programming. Prentice Hall PTR, Upper Saddle River, NJ, USA, 1997; 2. David Gries. The Science of Programming. Springer Verlag New York, Inc., Secaucus, NJ, USA, 1987; 3. S. S. Muchnick and N. D. Jones, editors. Program Flow Analysis: Theory and Applications. PrenticeHall: Englewood Cliffs, NJ, 1981; 4. Flemming Nielson, Hanne R. Nielson, and

			Chris Hankin. Principles of Program Analysis. SpringerVerlag New York, Inc., Secaucus, NJ, USA, 1999; 5. Alfred V. Aho, Monica S. Lam, Ravi Sethi, and Jeffrey D. Ullman. Compilers: Principles, Techniques, and Tools (2nd Edition). AddisonWesley Longman Publishing Co., Inc., Boston, MA, USA, 2006; 6. Michael Huth and Mark Ryan. Logic in Computer Science: Modelling and Reasoning about Systems. Cambridge University Press, New York, NY, USA, 2004; 7. Edmund M. Clarke, Jr., Orna Grumberg, and Doron A. Peled. Model checking. MIT Press, Cambridge, MA, USA, 1999.
CS640	COMPUTATIONAL COMPLEXITY	3-0-0--4	Complexity Classes. NP and coNP, Results on structure of NPcomplete sets, Sparse NPhard sets, Basic Inclusions and Separations, Nondeterministic Space Classes, Logarithmic Space, A PSPACE complete problem, Polynomial Hierarchy, PH through Alternating Quantifiers, Universal Relations, Probabilistic Classes, Schwartz Zippel Lemma and BPP, BPP and its relationship with other Complexity Classes.
CS640A	COMPUTATIONAL COMPLEXITY	3-0-0-0-9	Introduction to Computational Complexity. Complexity Classes. P and NP completeness. Hierarchy Theorems. Space Complexity. NL completeness. Savitchs Theorem. Immerman Szelepsc; enyi Theorem Polynomial Hierarchy. Alternating Turing Machines. Time Space Trade off for SAT. Circuit Complexity. Polynomial sized circuits. Uniformity. Circuit classes NC and AC. Randomized Computations. RP, BPP, ZPP. Relationship between BPP and other classes. Randomized space complexity. Interactive Proofs. Various protocols. IP PSPACE. Quantum Computation. The class BQP. Grovers search algorithm. Introduction to PCP and Hardness of Approximation. NP; PCP (poly(n), 1) Communication Complexity. Definition and lower bound techniques. Circuit Lower Bounds. Lower bounds on AC0. Counting Complexity. The class Todas Theorem. Tentative Topics (depending on availability of time). Hardness Amplification and Error Correcting Codes. Derandomization. Average case complexity.
CS641	MODERN CRYPTOLOGY	3-0-0--4	Basics of finite fields. Private and Publickey cryptography, existing crypto systems and their security. Crypto analysis of existing systems. Zero knowledge protocols, Oneway functions. Advanced protocols for different applications, e.g. echeque, ecash etc. Network and System level security issues.
CS641A	MODERN CRYPTOLOGY	3-0-0-0-9	Basics of finite fields. Private and Publickey cryptography, existing cryptosystems and their security. Cryptanalysis of existing systems. Zero knowledge protocols, Oneway functions. Advanced protocols for different applications, e.g. echeque,

			ecash etc. Network and System level security issues.
CS642	CIRCUIT COMPLEXITY THEORY	3-0-0--4	The course aims at a comprehensive overview of results on the circuit complexity classes and their relationship with the Turing based classes. The topics to be covered in the course are as follows: The class NC and its properties. Characterization of class P by circuits. The classes DLOG, NLOG, LogCF Land their properties. The class SC, proof of the relationship RL is a subsetof SC. The class NC1 and its characterizations. The class TC0 and its characterizations. The class ACC and its characterizations. The class AC0and its charecterizations. Lower bounds for AC0, for AC0[m] where m isa prime power and for TC02.
CS644	FINITE AUTOMATA ON INFINITE INPUTS	3-0-0--4	Finite automata on infinite words and trees: Complementation, determinization and algorithms for checking emptiness. Connections with logic: Finite automata and monadic second order (MSO)logic on words and trees. Decidability of MSO theory of various infinite graphs, methods of interpretation and unfolding. Applications; Decision procedures for temporal logics. Modelling, verification and synthesis of systems. Effective theory of infinite games.
CS644A	FINITE AUTOMATA ON INFINITE INPUTS	3-0-0-0-9	Finite automata on infinite words and trees: Complementation, determinization and algorithms for checking emptiness. Connections with logic: Finite automata and monadic second order (MSO)logic on words and trees. Decidability of MSO theory of various infinite graphs, methods of interpretation and unfolding. Applications: Decision procedures for temporal logics. Modelling, verification and synthesis of systems. Effective theory of infinite games.
CS645	TOPICS IN DESIGN AND ANALYSIS OF ALGORITHMS	3-0-0-0-4	Introduction. Disjoint set Union Find algorithms. Redblack trees. Selection algorithms and application to convex hull. Planar graph separators. Priority queues. Fusion trees and their applications to integer sorting. Fheaps, Rheaps Qheaps and AFheaps and general shortest paths and minimum spanning trees algorithms. Polynomial time algorithms for matching.
CS646	PARALLEL ALGORITHMS	3-0-0--4	Complexity measure for parallel algorithms. Parallel combinatorial algorithms: permutations with and without repetitions, combinations, derangements. Parallel searching algorithms: maximum/minimum, median, Kth largest/smallest element. Parallel sorting algorithms. Parallel graph algorithms: parallel graph searchand tree traversal algorithms, parallel algorithms for connectivity problems, parallel algorithms for path problems.
CS646A	PARALLEL ALGORITHMS	3-0-0-0-9	Complexity measure for parallel algorithms. Parallel combinatorial algorithms: permutations with and without repetitions, combinations, derangements. Parallel searching algorithms: maximum/minimum,

			median, Kth largest/smallest element. Parallel sorting algorithms. Parallel graph algorithms: parallel graph searchand tree traversal algorithms, parallel algorithms for connectivity problems, parallel algorithms for path problems.
CS647	ADVANCED TOPICS IN ALGORITHMS & DATA STRCUTURES	3-0-0--4	The course intends to deal with advanced aspects of algorithm: design and analysis including data structures, analysis and lower bound proofs, amortized complexity of algorithms. Fibonacci heaps and self adjusting search trees, Splay trees, linking and cutting trees. State-of-the-art algorithms for minimum spanning trees, shortest path problem. Network flows preflowpush algorithms, max flow algorithm, and scaling algorithms. Matching, blossoms, Micali Vazirani algorithm. Lower bound theory for parallel computations.
CS647A	ADVANCED TOPICS IN ALGORITHMS & DATA STRCUTURES	3-0-0-0-9	The course intends to deal with advanced aspects of algorithm: design and analysis including data structures, analysis and lower bound proofs, amortized complexity of algorithms. Fibonacci heaps and self adjusting search trees, Splay trees, linking and cutting trees. State-of-the-art algorithms for minimum spanning trees, shortest path problem. Network flows preflowpush algorithms, max flow algorithm, and scaling algorithms. Matching, blossoms, Micali Vazirani algorithm. Lower bound theory for parallel computations.
CS648	RANDOMIZED ALGORITHMS	3-0-0--4	Review of discrete probability; Notion of randomized algorithms, motivating examples; Markov, Chebyshev inequalities, Chernoff bounds; Probabilistic method; Hashing, finger printing; Random walks and Markov chains. Program checkers; Polynomial identities; Randomized complexity classes, Probabilistically checkable proofs; some number theoretic problems; Approximate counting.
CS648A	RANDOMIZED ALGORITHMS	3-0-0-0-9	Review of discrete probability; Notion of randomized algorithms, motivating examples; Markov, Chebyshev inequalities, Chernoff bounds; Probabilistic method; Hashing, finger printing; Random walks and Markov chains. Program checkers; Polynomial identities; Randomized complexity classes, Probabilistically checkable proofs; some number theoretic problems; Approximate counting.
CS653	FUNCTIONAL PROGRAMMING	3-0-0--4	ML (CAML dialect); Xcalculus and combinators; abstraction and higher order functions; lazy and eager evaluation; types, polymorphism and type inference; Equations and pattern matching; SECD machine; denotational semantics of functional languages; implementing functional languages.
CS653A	FUNCTIONAL PROGRAMMING	3-0-0-0-9	ML (CAML dialect); Xcalculus and combinators; abstraction and higher order functions; lazy and eager evaluation; types, polymorphism and type inference; Equations and pattern matching; SECD machine;

			denotational semantics of functional languages; implementing functional languages.
CS654	SOFTWARE ARCHITECTURE	3-0-0--4	In this course we study, typical software system structures (architectural styles), techniques for designing and implementing these structures, models for characterizing and reasoning about architectures, and tools for architectural modelling. Role of architecture in Software engineering; Enterprise Architectures, Zachmans Framework; Architectural Styles, Design Patterns; Architecture Description Languages; Productline architectures; Component based development.
CS654A	SOFTWARE ARCHITECTURE	3-0-0-0-9	In this course we study, typical software system structures (architectural styles), techniques for designing and implementing these structures, models for characterizing and reasoning about architectures, and tools for architectural modelling. Role of architecture in Software engineering; Enterprise Architectures, Zachmans Framework; Architectural Styles, Design Patterns; Architecture Description Languages; Productline architectures; Component based development.
CS663	COMPUTATIONAL GEOMETRY	3-0-0--4	Historical perspective: complexity notions in classical geometry. Towards computational geometry, geometric preliminaries, models of computation. Geometric searching: point location problems, location of a point in a planar subdivision, the slab method, the chain method, range searching problems. Convex hulls: problem statement and lower bounds. Grahams scan, Jarviss march, quick hull technique, convex hulls in more than one dimension, extension and applications. Proximity: divide and conquer approach, locus approach; the Voronoi diagram, lower bounds, variants and generalizations. Intersections, hiddenline and hidden surface problem. The geometry of rectangles: application of the geometry of rectangles, measure and perimeter of a union of rectangles, intersection of rectangles and related problems.
CS663A	COMPUTATIONAL GEOMETRY	3-0-0-0-9	Historical perspective: complexity notions in classical geometry. Towards computational geometry, geometric preliminaries, models of computation. Geometric searching: point location problems, location of a point in a planar subdivision, the slab method, the chain method, range searching problems. Convex hulls: problem statement and lower bounds. Grahams scan, Jarvissmarch, quick hull technique, convex hulls in more than one dimension, extensionand applications. Proximity: divide and conquer approach, locus approach; the Voronoi diagram, lower bounds, variants and generalizations. Intersections, hiddenline and hidden surface problem. The geometry of rectangles: application of the geometry of rectangles, measure and perimeter of a union of rectangles,

			intersection of rectangles and related problems.
CS671	INTRODUCTION TO NATURAL LANGUAGE PROCESSING	3-0-0--4	A computational framework for natural language. A framework such as LFG, GPSG or Panini in some depth. Partial description of English or an Indian language in the frame work, lexicon, algorithms and data structures for implementation of the framework. Introduction to semantics and knowledge representation. Some applications like machine translation, database interface.
CS671A	INTRODUCTION TO NATURAL LANGUAGE PROCESSING	3-0-0-0-9	A computational framework for natural language. A framework such as LFG, GPSG or Panini in some depth. Partial description of English or an Indian language in the frame work, lexicon, algorithms and data structures for implementation of the framework. Introduction to semantics and knowledge representation. Some applications like machine translation, database interface.
CS674	MACHINE LEARNING & KNOWLEDGE DISCOVERY	3-0-0--4	This course will explore different machine learning, knowledge discovery anddata mining approaches and techniques: Concept Learning, Decision Tree Learning, Clustering and instance-based learning, Rule induction and inductive learning, Bayesian networks and causality, Neural networks, Genetic algorithms, Reinforcement learning, Analytical, learning.
CS676	COMPUTER VISION AND IMAGE PROCESSING	3-0-0--4	Human and Computer Visioon, Image Representation and Modelling, Line andEdge detection, labeling, Image Segmentation. Pattern Recognition: Statistical, Structural, Neural and Hybrid Techniques. Training and Classification. Document Analysis and Optical Charecter Recognition. Object Recognition Scene Matching and Analysis, Robotic Vision. Role of Knowledge.
CS676A	COMPUTER VISION AND IMAGE PROCESSING	3-0-0-0-9	Human and Computer Visioon, Image Representation and Modelling, Line and Edge detection, labeling, Image Segmentation. Pattern Recognition: Statistical, Structural, Neural and Hybrid Techniques. Training and Classification. Document Analysis and Optical Charecter Recognition. Object Recognition Scene Matchingand Analysis, Robotic Vision. Role of Knowledge.
CS678	LEARNING WITH KERNELS	3-0-0-0-4	Kernel based methods in machine learning have become a major paradigm in machine learning in the last decade. The methods have also found widespread application in pattern classification problems. This course aims to first discuss the basic principles of kernel - based learning methods and then branch off into some areas of current research like: techniques for finding optimal kernels, error bound analysis novelty detection etc.
CS678A	LEARNING WITH KERNELS	3-0-0-0-9	Kernel based methods in machine learning have become a major paradigm in machine learning in the

			last decade. The methods have also found widespread application in pattern classification problems. This course aims to first discuss the basic principles of kernel -based learning methods and then branch off into some areas of current research like: techniques for finding optimal kernels, error bound analysis novelty detection etc.
CS679	MACHINE LEARNING FOR COMPUTER VISION	3-0-0-0-4	1. Probability basics and common probability distributions. 2. Fitting Probability models (ML, MAP, Bayesian). 3. Normal distribution. 4. Regression 5. Classification. 6. Graphical models. 7. Temporal models. **Course Reference**: 1. Computer Vision: Models, Learning and Inference by Simon J.D. Prince; 2. Pattern Recognition and Machine Learning by Christopher M. Bishop; 3. Prababilistic Graphical Models: Principles and Techniques by Daphne Koller and Nir Friedman.
CS679A	MACHINE LEARNING FOR COMPUTER VISION	3-0-0-0-9	1. Probability basics and common probability distributions. 2. Fitting Probability models (ML, MAP, Bayesian). 3. Normal distribution. 4. Regression 5. Classification. 6. Graphical models. 7. Temporal models. **Course Reference**: 1. Computer Vision: Models, Learning and Inference by Simon J.D. Prince; 2. Pattern Recognition and Machine Learning by Christopher M. Bishop; 3. Prababilistic Graphical Models: Principles and Techniques by Daphne Koller and Nir Friedman.
CS680	CATEGORY THEORY	3-0-0--4	Introduction: Basic definition and diagram; sources and sinks; monicity andepicity; isomorphisms of objects and morphisms; duality; Universal Structures: Initial terminal and zero; Category of sources and sinks; product; equalizer; regular epicity and monicity; pullback; completeness; kernel; Normal Categories: Normal hierarchy; extension of categories; factorization; chains and exactness; Morphism algebra: Biproduct; semiadditive category; Additive category; Functors:Natural transformation; categories on natural transformation; property preservingand reflecting functors; Diagram isomorphism; Similar categories; generalization of limit and colimit; Hreflection morphism and adjoint functor; Representable functors Category in context of another category; Application to Logic (Topoi);application to Programming Languages.
CS680A	CATEGORY THEORY AND APPLICATIONS IN COMPUTING	3-0-0-0-9	Introduction: Basic definition and diagram; sources and sinks; monicity andepicity; isomorphisms of objects and morphisms; duality; Universal Structures:Initial terminal and zero; Category of sources and sinks; product; equalizer; regular epicity and monicity; pullback; completeness; kernel; Normal Categories: Normal hierarchy; extension of

			categories; factorization; chains and exactness; Morphism algebra: Biproduct; semiadditive category; Additive category; Functors: Natural transformation; categories on natural transformation; property preserving and reflecting functors; Diagram isomorphism; Similar categories; generalization of limit and colimit; Hreflection morphism and adjoint functor; Representable functors Category in context of another category; Application to Logic (Topoi);application to Programming Languages.
CS681	COMPUTATIONAL NUMBER THEORY AND ALGEBRA	3-0-0-0-4	Elementary operations: the complexity of basic operations like additions, multiplications for integers and polynomials. Polynomials: The complexity of factorization, irreducibility testing, ideal membership etc for polynomials overfinite fields. Motivating example: Reedsoloman codes. Integer Lattices: the complexity of finding a short vector in an integer lattice. Motivating example; polynomial factorization. Integers: The complexity of factorization, primality testing, discrete log computation etc for integers. Motivating examples: RSA and El Gamal cryptosystems. Elliptic curves: the complexity of addition, point counting etc. for elliptic curves. Motivating examples: Elliptic curve cryptosystems and integer factoring.
CS681A	COMPUTATIONAL NUMBER THEORY AND ALGEBRA	3-0-0-0-9	Elementary operations: the complexity of basic operations like additions, multiplications for integers and polynomials. Polynomials: The complexity of factorization, irreducibility testing, ideal membership etc for polynomials overfinite fields. Motivating example: Reed soloman codes. Integer Lattices: the complexity of finding a short vector in an integer lattice. Motivating example; polynomial factorization. Integers: The complexity of factorization, primality testing, discrete log computation etc for integers. Motivating examples: RSAand El Gamal cryptosystems. Elliptic curves: the complexity of addition, point counting etc. for elliptic curves. Motivating examples: Elliptic curve cryptosystems and integer factoring.
CS682A	QUANTUM COMPUTING		this course will focuse on the computer science aspects of quantum computing foundation: hilbert space (finit dimensional). Axioms of quantam probabality. quantam vs classical probability. quantam computing: turing machine, Boolean circuits, quantam circuits, universality. Simon’s problem, phase finding, shor’s algorithm, grovers algorithm, probabiity amplification. Some applications on quantam information processing: quantum error correction. knilllaflamme theorem, stabiliser codes. basic of quantam information theory additional topics: baseed on the interests of the audience.
CS697	SPECIAL TOPICS IN	0-0-0--4	Special and advanced topics in different areas of

	COMPUTER SCIENCE		Computer Science and Engineering will be covered under this course.
CS697A	SPECIAL TOPICS IN COMPUTER SCIENCE	0-0-0-0-9	Special and advanced topics in different areas of Computer Science and Engineering will be covered under this course.
CS698.	B TECH PROJECT	----6	B. TECH PROJECT
CS698P	APPLICATIONS OF MARKOV CHAINS IN COMBINATORIAL OPTIMIZATION AND IN EVOLUTIONARY DYNAMICS		applications of markov chains in co and evolutionary dynamics
CS698V	STATISTICAL NATURAL LANGUAGE PROCESSING		Natural language (NL) refers to the language spoken/written by humans. NL is the primary mode of communication for humans. With the growth of the world wide web, data in the form of text has grown exponentially. It calls for the development of algorithms and techniques for processing natural language for the automation and development of intelligent machines. This course will primarily focus on understanding and developing linguistic techniques, statistical learning algorithms and models for processing language. We will have a statistical approach towards natural language processing, wherein we will learn how one could develop natural language understanding models from statistical regularities in large corpora of natural language texts while leveraging linguistics theories. Besides regular quizzes and assignments, the course will have a major project component where participants would have to work on an open research problem in NLP.
CS699	M TECH THESIS	0-0-0-0-	M. Tech. Thesis
CS699.	M TECH THESIS (FOR DUAL DEGREE ONLY)		m tech thesis (for dual degree only)
CS711A	INTRODUCTION TO GAME THEORY AND MECHANISM DESIGN		Indian Institute of Technology Kanpur.Department of Computer Science and Engineering New Course Proposal Title: Introduction to Game Theory and Mechanism Design Course No: CS711 Units: 3-0-0-0 (9) Pre-requisites: Familiarity with formal mathematical reasoning, probability theory, calculus, basics of computational complexity, and computer programming Proposed by: Swaprava Nath. Estimated Enrollment: 50 or less Departments which may be interested: CSE, MTH, EE, IME, ECO Level of the course: PG Short Description. This course is an introduction to classical game theoretic ideas and results with the aim to design mechanisms that satisfy desirable axioms. The course will introduce ideas of rationality and intelligence, cover non-cooperative games (including complete information simultaneous move and sequential games, and later incomplete information games), cooperative games (ideas of

			coalition, core, Shapley value, neucleolus etc), and introduce mechanism design framework (social choice and welfare functions, Arrow's impossibility result, unrestricted preferences and Gibbard-Satterthwaite result, domain restriction: single-peaked, task allocation domains, quasi-linear preferences), and demonstrate applications of these ideas in practice. A tentative list of topics are as follows: Non-cooperative game theory; Quantitative models of strategic interaction: rationality, intelligence, common knowledge;Complete information simultaneous move games; normal form representation; Ideas of equilibria: domination of strategies, Nash equilibrium;Existence results for mixed and pure Nash equilibrium; Correlated equilibrium; Complete information sequential move games extensive form representation; Perfect and imperfect information extensive form games; Equilibria concepts; subgame perfect equilibrium, perfect Bayesian equilibrium, analogies with pure and mixed Nash equilibrium;Incomplete information games; Bayesian games; Equilibria concepts tied to the belief system;Nash and Bayesian equilibria in incomplete information games; Cooperative Game Theory;Utility representation in form of coalition;Transferable utilities game; Imputation, core, Shapley value, nucleolus Introduction to mechanism design;Incomplete information to player types Social welfare function, Arrow’s impossibility result;Social choice function, Gibbard-Satterth waite result;Domain restriction;Single-peaked preferences; Task allocation domain; Quasi-linear preferences;Some real world applications of mechanism design ReferencesNo specific textbook. However, the following books and lecture notes may be useful. **Course Reference**: 1. Yoav Shoham and Kevin Leyton-Brown: Multiagent Systems (www.masfoundations.org) 2. Martin Osborne: An Introduction to Game Theory; 3. Y. Narahari: Game Theory and Mechanism Design; 4. Debasis Mishra Game Theory course notes: http://www.isid.ac.in/~dmishra/gm1doc/notes_2016.pdf Mechanism Design course notes: http://www.isid.ac.in/dmishra/gmdoc/mdnotes.pdfNote : This course has some content overlap with CS656 and CS785. However, the proposed course provides a view of the evolution of the ideas in non-cooperative games; it differs particularly in the areas of sequential games and their equilibria concepts. It also covers cooperative games. On the mechanism design front, it provides a panoramic view of different domains of social choice and welfare that helps distinguish the advantages and limitations of these domains.
CS719	DATA STREAMING:	3-0-0--4	Motivating applications: network monitoring, sensor

	ALGORITHMS & SYSTEMS		networks, need for highly efficient processing of high speed and high -volume data streams, Space and time efficient randomized algorithms as a candidate solution, models of data streams. Basics of randomization: elementary probability theory,expectation, linearity of expectation, variance, Markov and Chebychevs inequality,Chernoff and Hoeffding (CH) tail inequalities, hash functions, limited independence, CHbounds for limited independence.Finding frequent items in data streams, Estimating distinct item queries, Estimating frequency moments, estimating join sizes, Approximate histograms over data streams, Transforms over data streams, wavelets, fourier and DCT clustering over data streams, Applications to graphs.
CS719A	DATA STREAMING: ALGORITHMS & SYSTEMS	3-0-0-0-9	Motivating applications: network monitoring, sensor networks, need for highly efficient processing of high speed and high-volume data streams, Spaceand time efficient randomized algorithms as a candidate solution, models of data streams. Basics of randomization: elementary probability theory, expectation, linearity of expectation, variance, Markov and Chebychevs inequality, Chernoff and Hoeffding (CH) tail inequalities, hash functions, limited independence, CHbounds for limited independence. Finding frequent items in data streams, estimating distinct item queries, Estimating frequency moments, estimating join sizes, Approximate histograms over data streams, Transforms over data streams, wavelets, fourier and DCT clustering over data streams, Applications to graphs.
CS720	VLSI TESTING AND FAULT TOLERANCE	3-0-0--4	The course is primarily intended to familiarize students with the problemof testing large and complex electronic circuits. Various techniques to solvethis problem and concepts of design for easy testability (DFT) will be discussed. Topics related to fault modeling and fault simulation to evaluate the fault coverage of test vectors will be covered in detail. The problem of reducedyield and reliability of circuits in presence of faults will be discussed and techniques to improve the yield and reliability of these circuits by introducing fault tolerance measures will also be covered. Various redundancy techniques like structural, time, information and software redundancy will also be discussed in detail.
CS720A	VLSI TESTING AND FAULT TOLERANCE	3-0-0-0-9	The course is primarily intended to familiarize students with the problem of testing large and complex electronic circuits. Various techniques to solvethis problem and concepts of design for easy testability (DFT) will be discussed. Topics related to fault modeling and fault simulation to evaluate the fault coverage of test vectors will be covered in detail. The problem of reduced yield and reliability of circuits in presence of faults will be discussed and techniques

			to improve the yield and reliability of these circuits by introducing fault tolerance measures will also be covered. Various redundancy techniques like structural, time, information and software redundancy will also be discussed in detail.
CS727	TOPICS IN INTERNET TECHNOLOGIES	3-0-0--4	Today the Internet is being used for myriad of applications electronic publishing, electronic commerce, distance education, collaborative working, etc. This course intends to investigate the underlying principles and practices that support these applications. Introduction to computer networks; Content preparation HTML, DHTML, VRML, SGML, XML and other markup schemes; Images compression, formats; Audio compression, formats; Content Delivery protocols HTTP and variants, Internet servers, proxy servers; Search engines;Data on the web; Content Display browsers, plugins, helper applications; Interactivity Java, ActiveX; Component technologies, Javabeans, CORBA; Security, Electronic payment systems, Firewalls, Encryption, Watermarks; Performance, Benchmarking the Web.
CS738	ADVANCED COMPILER OPTIMIZATIONS	3-0-0--4	Introduction to Advanced topics, Compiler Algorithms Notation, Symbol tablestructure, Intermediate representation, Run time support, Producing code generators automatically, Control flow analysis, Data flow analysis, Dependence analysis and dependence graphs, Alias analysis, Introduction to optimizations, Early optimizations, Redundancy elimination, Loop optimizations, procedure optimizations, Register allocation, Code scheduling, control flow and low level optimizations, Inter procedural Analysis and optimizations, Optimization formemory hierarchy, Case studies.
CS743	ADVANCED GRAPH ALGORITHMS	3-0-0--4	Review of important sequential graph algorithms. Introduction to parallel models for computation. General techniques for fast parallel computations on vectors, lists and their applications to design of efficient parallel graph algorithms. Parallel dynamic programming and its applications to expression graphs. State-of-art algorithms for depth first search of directed and undirected graphs. NCalgorithms for STnumbering and open ear decomposition. Parallel algorithms for graph optimization problems. Algorithms for graph coloring. Decomposition of graph into simpler subgraphs. Equivalence relations and classes in graphs. Parallel planarity testing.
CS743A	ADVANCED GRAPH ALGORITHMS	3-0-0-0-9	Review of important sequential graph algorithms. Introduction to parallel models for computation. General techniques for fast parallel computations on vectors, lists and their applications to design of efficient parallel graph algorithms. Parallel dynamic programming and its applications to expression graphs. State-of-art algorithms for depth first search of

			directed and undirected graphs. NCalgorithms for STnumbering and open ear decomposition. Parallel algorithmsfor graph optimization problems. Algorithms for graph coloring. Decomposition of graph into simpler subgraphs. Equivalence relations and classes in graphs. Parallel planarity testing.
CS744A	PSEUDO-RANDOM GENERATORS	3-0-0-0-9	Pseudo random generators are efficiently computable functions that stretch and input random string to a much bigger sized string such that the output string appears random to resource bounded computations. These functions have become one of the fundamental objects to study in complexity theory because of their utility. They are used to derandomize randomized algorithms, formalize notions of cryptographic security, obtain lower bounds on the complexity of problems etc. (unfortunately, as of now very few constructions of pseudo random generators are provably known although many are conjectured). In this course, we study pseudorandom generators and their connections in depth. The topics covered in the course are as follows: Pseudorandom generators: definitions and Existence. Pseudorandom generators of small stretch: Definitions of cryptographic security, Equivalence of oneway functions and pseudorandom generators, some functions conjectured to be oneway functions, Pseudorandom function generators. Pseudorandom generators of large stretch: Equivalence of lower bounds and pseudorandom generators, Known pseudorandom generators against small depth circuits and small space classes, Extractors and pseudorandom generators. Pseudorandom generators against arithmetic circuits: Equivalence of lower bounds and pseudorandom generators, A function conjectured to be pseudo random.
CS749A	ELLIPTIC CURVES AND THEIR APPLICATIONS	3-0-0-0-9	elliptic curves over reals: weiertrass equation, endomorphisms elliptic curves over complex numbers: equivalence with tori, symmetrics, divisors, and weil pairing, elliptic curves over rationals. elliptic curves over finite fields, application public key encryption algorathm. applications: proof of fermat’s last theorem.
CS771A	INTRODUCTION TO MACHINE LEARNING		machine learnning is the discipline of designing algorithms that machienes to learn patterns and conepts from data without being explictly programmed. this course will be an introduction to te design of machine learning algorithms, with a modern outlook focusing on recent advances, and example of real-world application of machine learining algorithms, introduction to preliminaries in linear algebra, and probability theory, supervised learning. unsuperwised learning. Practical aspects; additional topics (a subset to be covered depending on interest and time)

CS799	PHD THESIS	----	Ph. D. Thesis
ESC101A	FUNDAMENTAL OF COMPUTING	3-1-3-0-14	Stored program concept (with simple computer simulator), machine language and instruction formats, assembly language for the simple computer. Integer representation, finite representation of real numbers, overflow, underflow, errors due to finite representations. Expressions, values and variables, types, lvalue, rvalue, unary, binary, ternary operations. Conditionals, if then, if then else, nested conditionals, switchcase Loops, for, while, repeat, loop invariants, precondition, postcondition. Functions and return values, arguments, passby value, effect of passing pointers (like passby reference). Recursion. Arrays, enums, searching, sorting. Pointers, lists, dynamic data structures, stack, queue, graphs, trees related algorithms, memory and its management. Elementary complexity motivation, concrete complexity, big O notation Linux tools, introduction to shell programming. Elementary numerical problem solving will addressedlargely through some labs e.g. root finding, solutions of systems of linear equations, integration, solution of ODEs. **Course Reference**: 1. Brian W Kernighan and Dennis M Ritchie, The C Programming Language,2nd Ed. ANSI C version, Pearson, 2006.
ESC101N	FUNDAMENTAL OF COMPUTING	3-1-3-0-5	Stored program concept (with simple computer simulator), machine language and instruction formats, assembly language for the simple computer. Integer representation, finite representation of real numbers, overflow, underflow, errors due to finite representations. Expressions, values and variables, types, lvalue, rvalue, unary, binary, ternary operations. Conditionals, if-then, if-then-else, nested conditionals, switchcase. Loops, for, while, repeat, loop invariants, precondition, postcondition. Functions and return values, arguments, passby value, effect of passing pointers (like passby reference). Recursion. Arrays, enums, searching, sorting. Pointers, lists, dynamic data structures, stack, queue, graphs, trees related algorithms, memory and its management. Elementary complexity motivation, concrete complexity, big O notation. Linux tools, introduction to shell programming. Elementary numerical problem solving will addressed largely through some labs e.g. root finding, solutions of systems of linear equations, integration, solution of ODEs. **Course Reference**: 1. Brian W Kernighan and Dennis M Ritchie, The C Programming Language,2nd Ed. ANSI C version, Pearson, 2006.
ESO207A	DATA STRUCTURE & ALGORITHM	3-0-0-0-9	Order Analysis: Objectives of time analysis of algorithms; Bigoh and Theta notations, Data Structures: Arrays, Linked lists, Stacks (example: expression evaluation), Binary search trees, RedBlack

			trees, Hash tables, Sorting and Divide and Conquer Strategy: Mergesort; DandC with Matrix Multiplication as another example, Quicksort with average case analysis, Heaps and heapsort, Lower bound on comparison based sorting and Counting sort, Radix sort, Btrees, Dynamic Programming: methodology and examples (Fibonacci numbers, matrix sequence, multiplication, longest common subsequence, convex polygon triangulation), Greedy Method: Methodology, examples (lecture scheduling,process scheduling) and comparison with DP (more examples to come later in graph algorithms), Graph Algorithms: Basics of graphs and their representations, BFS, DFS, Topological sorting, Minimum spanning trees (Kruskal and Prims algorithms and brief discussions of disjoint set and Fibonacci heap data structures), Shortest Paths (Dijkstra, BellmanFord, FloydWarshall).
ESO211	DATA STRUCTURES AND ALGORITHMS	3-0-0-0-4	Order Analysis: Objectives of time analysis of algorithms; Bigoh and Theta notations, Data Structures: Arrays, Linked lists, Stacks (example: expression evaluation), Binary search trees, RedBlack trees, Hash tables, Sorting and Divideand Conquer Strategy: Mergesort; DandC with Matrix Multiplication as another example, Quicksort with average case analysis, Heaps and heapsort, Lowerbound on comparison based sorting and Counting sort, Radix sort, Btrees, Dynamic Programming: methodology and examples (Fibonacci numbers, matrix sequence, multiplication, longest common subsequence, convex polygon triangulation), Greedy Method: Methodology, examples (lecture scheduling, process scheduling) and comparison with DP (more examples to come later ingraph algorithms), Graph Algorithms: Basics of graphs and their representations,BFS, DFS, Topological sorting, Minimum spanning trees (Kruskal and Primsalgorithms and brief discussions of disjoint set and Fibonacci heap data structures), Shortest Paths (Dijkstra, BellmanFord, FloydWarshall).
Others	Others		

ECONOMICS

ECONOMICS

BS								Template No. ECO-1
	SEMESTER							
	1st	2nd	3rd	4th	5th	6th	7th	8th
C	MTH101A [11]	MTH102A [11]	COM200A [05]	ESO/SO-3 [~10]*	ECO301A [09]	ECO311A [09]	ECO321A [09]	ECO413A [09]
O	PHY102A [11]/ PHY103A [11]	PHY103A [11]/ PHY102A [11]	ECO201A [09]	OE-1 [09/11]	ECO341A [12]	ECO342 [12]	ECO411A [09]	DE-4 [09]
U	PHY101A [03]/ CHM101A [03]	CHM101A [03]/ PHY101A [03]	ESO/SO-1 [~10]*	ESC201A [14]/ HSS-2 (Level-1) [11]	OE-2 [09]	HSS-4 (Level-2) [09]	ECO412A [09]	HSS-5 (Level-2) [09]
R	PE101A [03]	CHM102A [08]	ESO/SO-2 [~10]*	ECO221A [09]	HSS-3 (Level-2) [09]	DE-1 [09]	DE-3 [09]	OE-6 [09]
S	ENG112A/HSS-1 (Level-1) [11]	PE102A [03]	HSS-2 (Level-1) [11]/ ESC201A [14]	ECO261A [09]	ESO/SO-4 [~10]*	OE-3 [09]	OE-4 [09]	OE-7 [09]
E S	LIF101A [06] + TA101A [09]/ ESC101A [14]	ESC101A [14]/ LIF101A [06] + TA101A [09]	TA202A [06]/ TA201A [06]	TA201A [06]/ TA202A [06]	ECO397A [02] UGP-1 [04] (extra credits)	UGP-2/ DE-2 [09] (ECO399A)	UGP-3/ OE-5 [09] (ECO498A)	UGP-4 [09] (extra credits)
	53/54	50/51	51/54*	54-59*	51/55*	57	54	45/54

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	107	Credits
Department Elective (DE)	:	36	Credits
Open Elective (OE)	:	63	Credits
*SO/ ESO	:	40	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	419	Credits

REMARKS:

1) *ESO/SO courses are available in 6-14 credits each. Students need to ensure that their total ESO/SO credits total up to AT LEAST 40, including minimum one course from each of the two categories (ESO and SO), without going over 65 credits in any given semester.
2) UGP-1 & UGP-4 are optional and do not count towards DE/OE credits.
3) DE credits may include UGP-2.
4) OE credits may include UGP-3.
5) Upto 36 OE credits may be waived from the minimum requirements for students opting for either Dual Degree or Double Major programme.

BS -MS PG (Part- Category A) (from the same department)		Template No. ECO-2
C	9th	10th
O	DE-PG-1(09) course of Economics must be taken	PG-3(09)
U	DE-PG-2(09) course of Economics must be taken	PG-4(09)
R	Ms Project (18)	Ms Project (27)
S		
E S	36	45

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION

PG Component	:	36 Credits
MS Project Component	:	45 Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ PUGC Convener.
2) Course credits and MS Project credits mentioned under dual degree template are only for MS part of the Programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG Programme.
3) Up to 36 OE credits may be used from the BS requirements to fulfil requirements for the BS-MS dual degree programme. These will be waived from the BS programme and counted towards PG requirements.

C	BT/BS-MS (Category –B)(from other departments)			Template No. ECO3
O	UG Pre Requisites		PG Requirements	
U	Odd Semester	Even Semester	Odd Semester	Even Semester
R	ECO201 A(09)/ECO101 A(11)	ECO 221A(09)	DE-PG-1(09) course of Economics must be taken	DE-PG-3(09) course of Economics must be taken
S	ECO341A(12)	ECO 342A(12)	DE-PG-2(09) course of Economics must be taken	PG-4(09)
E	ECO301A(09)		Ms Project (18)	Ms Project (27)
S	Eco321A(09)			
	39	21	36	45

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION

PG Component	:	36 Credits
MS Project Component	:	45 Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ PUGC Convener.
2) Course credits and MS Project credits mentioned under dual degree template are only for MS part of the Programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG Programme.
3) Up to 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the BT/BT-MS dual degree programme. These will be waived from the department's BT/BS programme and counted towards PG requirements.

DOUBLE MAJOR	Template No. ECO-4
Odd Semester	Even Semester
ECO201A [09]/ ECO101A [11]	ECO221A [09]
ECO341A [12]/ MTH416A [11]	ECO261A [09]
ECO301A [09]	ECO311A [09]
ECO321A [09]	ECO342A [12]
ECO411A [09]	ECO413A [09]
ECO412A [09]	
56 – 59	48

MINIMUM MANDATORY CREDITS FOR SECOND MAJOR IN ECONOMICS: 104 CREDITS

REMARKS:

1. Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.

DEPARTMENT OF ECO

Courses ID	Course Title	Credits L-T-P-D-[C]	Content
ECO100	INTRODUCTION TO PROFESSION	2-0-0--0	For whom the bell tolls; What is Economics? Basic concepts of supply anddemand; Central Problems of very economic society; Development, freedom andopportunities; Dilemma of development; Linkages between technology, economicsand environment; Business organizations and income; The role of economistin business and industry; The role of economist in societal development; Therole of economist in governance.
ECO101	INTRODUCTION TO ECONOMICS	3-1-0-0-4	Definition and central problems of Economics, Microeconomics vs Macroeconomics, Normative vs. Positive Economics, Stock vs. Flow variables; Aggregate economic variables: Gross Domestic Product (GDP), Gross National Product (GNP), National income, Money supply, Price index and inflation rate, Unemployment rate, Exchange rate; Laws of demand and supply, Elasticity, Market equilibrium, Consumer and producer surplus, Price controls; Utility theory: Laws of diminishing marginal and equimarginal utility, Indifference curves and budget constraint, Optimizing conditions, Substitution and income effects; Theory of production and cost: Law of variable proportion, Shortrun cost functions, Isoquant and isocost, Optimizing conditions, Longrun cost functions; Types of market: Perfect Competition, Monopoly, Oligopoly, Monopolistic Competition. **Course Reference**: 1. Economics, by Paul A. Samuelson, any edition; 2. Macroeconomics, by N. G. Mankiw, 6th edition; 3. Microeconomics, by R. S. Pindyck, D. L. Rubinfeld and P. L. Mehta, 6th edition; 4. Intermediate Microeconomics, by H. R. Varian, 6th edition; 5. Microeconomic Theory, by J. M. Henderson and R. E. Quandt, 3rd edition; 6. Microeconomic Analysis, by R. R. Barthwal, any edition.
ECO101A	INTRODUCTION TO ECONOMICS	3-1-0-0-11	Definition and central problems of Economics, Microeconomics vs.Macroeconomics, Normative vs. Positive Economics, Stock vs. Flow variables; Aggregate economic variables: Gross

			domestic product (GDP), Gross national product (GNP), Nationalincome, Money supply, Price index and inflation rate, Unemployment rate, Exchange rate;Laws of demand and supply, Elasticity, Market equilibrium, Consumer and producer surplus,Price controls; Utility theory: Laws of diminishing marginal and equimarginal utility,Indifference curves and budget constraint, Optimizing conditions, Substitution and income effects; Theory of production and cost: Law of variable proportion, Shortrun cost functions,Isoquant and isocost, Optimizing conditions, Longrun cost functions; Types of market: Perfect Competition, Monopoly, Oligopoly, Monopolistic Competition. **Course Reference**: 1. Economics, by Paul A. Samuelson, any edition; 2. Macroeconomics, by N. G. Mankiw, 6th edition; 3. Microeconomics, by R. S. Pindyck, D. L. Rubinfeld and P. L. Mehta, 6th edition; 4. Intermediate Microeconomics, by H. R. Varian, 6th edition; 5. Microeconomic Theory, by J. M. Henderson and R. E. Quandt, 3rd edition; 6. Microeconomic Analysis, by R. R. Barthwal, any edition.
ECO201	MICROECONOMICS - I	3-1-0--4	Theory of consumer behavior; Theory of demand and supply; Production theory; Costs of production; Markets Perfect competition, Monopoly oligopoly; Theory of distribution; Pricing.
ECO201A	MICROECONOMICS I	3-0-0-0-9	Theory of consumer behavior; Theory of demand and supply; Production theory; Costs of production; Markets Perfect competition, Monopoly oligopoly; Theory of distribution; Pricing.
ECO202	MACROECONOMICS	3-1-0--4	Circular Flow of Income, Output and Expenditure, National Income Accounting Methods, Classical Model, Keynesian Cross Model Theories of Consumption and Investment, Demand for Money, ISLM Model, Macroeconomic Problems, Balance of Payments Account, Exchange Rate Systems, and Open Economy Macroeconomics.
ECO221A	MACROECONOMICS I	3-0-0-0-9	Circular Flow of Income, Output and Expenditure, National Income Accounting Methods, Classical Model, Keynesian Cross Model.Theories of Consumption and Investment, Demand for Money, ISLM Model, Macroeconomic Problems, Balance of Payments Account, Exchange Rate Systems, and Open Economy Macroeconomics.
ECO231	ECONOMIC PROBLEMS AND POLICY	3-1-0--4	Global economic issues and challenges; From global to national issues; Economic institutions: markets, government, and social groups; Indian economic issues and policy; Indian agriculture and rural economy; Industrial economy; Policy towards social infrastructure; Trade and foreign exchange policy; Policy towardsinternational capital flow
ECO261	INTRODUCTION TO MATHEMETICAL ECONOMICS	3-0-0-0-4	Basic Mathematical Logic; Set Theory; Review of Functions of a Single Variable and Its Application in Economics: Choice, Utility and Aggregation; Functions of Several Variables: Level Curves, Homogeneity and Homotheticity, Concavity and Convexity; Static Optimization: Unconstrained Optimization, Constrained Optimization with Equality and Inequality Constraints; The Envelope Theorem and Duality; Dynamics and Dynamic Optimization.
ECO261A	INTRODUCTION	3-0-0-0-9	Basic Mathematical Logic; Set Theory; Review of Functions of a

	TO MATHEMATICAL ECONOMICS		Single Variable and Its Application in Economics: Choice, Utility and Aggregation; Functions of Several Variables: Level Curves, Homogeneity and Homotheticity, Concavity and Convexity; Static Optimization: Unconstrained Optimization, Constrained Optimization with Equality and Inequality Constraints; The Envelope Theorem and Duality; Dynamics and Dynamic Optimization.
ECO301A	MICROECONOMICS II		Static games with complete information Nash Equilibrium; Dynamic games with complete information Subgame perfect Nash Equilbrium; Static games with incomplete information Bayesian Nash Equilibrium; Dynamic games with incomplete information Perfect Bayesian Nash Equilibrium, Sigmaling games; Adverse Selection and Moral Hazard; Exchange Economy and definition of Competitive Equilibrium; Pareto efficiency and Pareto set; One consumer one producer econnomy; Two sector production economy; First Fundamental theorem of Welfare Economics; Second Fundamental theorem of Welfare Economics; Pareto optimality and social welfare functions; Public goods and externalities; Property rights and Coase theorem; Social Choi d Theory
ECO303	MICRO ECONOMICS II	3-1-0-0-4	Static games with complete information Nash Equilibrium; Dynamic games with complete information Subgame perfect Nash Equilbrium; Static games with incomplete information Bayesian Nash Equilibrium; Dynamic games with incomplete information Perfect Bayesian Nash Equilibrium, Sigmaling games; Adverse Selection and Moral Hazard; Exchange Economy and definition of Competitive Equilibrium; Pareto efficiency and Pareto set; One consumer one producer econnomy; Two sector production economy; First Fundamental theorem of Welfare Economics; Second Fundamental theorem of Welfare Economics; Pareto optimality and social welfare functions; Public goods and externalities; Property rights and Coase theorem; Social Choid Theory.
ECO311	ECONOMETRIC METHODS	3-1-0-0-4	Economic growth versus economic development, indicators of economic development, economic inequality, poverty, population growth and economic development, models of dual economy, land tenancy arrangements, rural savings, rural or informal credit markets, history and institutions, role of governance in economic development.
ECO311A	DEVELOPMENT ECONOMICS	3-0-0-0-9	Economic growth versus economic development, indicators of economic development, economic inequality, poverty, population growth and economic development, models of dual economy, land tenancy arrangements, rural savings, rural or informal credit markets, history and institutions, role of governance in economic development.
ECO312	ECONOMETRIC PRACTICE	3-1-0-0-4	Economic theory and econometrics; Types of models; Sources of data; Microeconometric models; Models of the firm and industry; Applications to development economics; Macroeconometric models; Models of international trade and finance; Deterministic and stochastic models
ECO321	INDUSTRIAL ECONOMICS	3-1-0--4	Microeconomic foundations of Macroeconomics, Representative agent model, Application of representative agent model in asset pricing, consumption theories etc., Longrun economic growth

			models, Models of shortrun economic fluctuations, Macroeconomic policy debates validation and application of growth/business cycle models.
ECO321A	MACROECONOMICS-II		Microeconomic foundations of Macroeconomics, Representative agent model, Application of representative agent model in asset pricing, consumption theories etc., Longrun economic growth models, Models of shortrun economic fluctuations, Macroeconomic policy debates validation and application of growth/business cycle models.
ECO332	DEVELOPMENT ECONOMICS	3-1-0-0-4	Economic growth versus economic development, indicators of economic development, economic inequality, poverty, population growth and economic development, models of dual economy, land tenancy arrangements, rural savings, rural or informal credit markets, history and institutions, role of governance in economic development.
ECO333	MONEY AND BANKING	3-1-0-0-4	Functions of Money and Interest Rates; Money Supply; Money Market; Regulatoryand promotional institutions; Banking institutions; and Term structure of Interest Rates.
ECO341	ENVIRONMENTAL ECONOMICS AND POLICY	3-1-0--4	Classical Linear Regression Model (CLRM), Assumptions of the CLRM and its violation, Hypothesis Testing, Gauss Markov Theorem, Properties of the Estimator, Multiple Regression Model, Hetero scedasticity, Autocorrelation and Multicollinearity, Lagged Variables, Dummy Variables, Specification Bias, Simultaneous Equations, Introduction to Time Series, Discrete Choice, Limited Dependent Variable and Panel Data Models, Estimation Procedures Ordinary Least Square(OLS), Generalized Least Squares(GLS), IV(Instrumental Variable), Maximum Likelihood Estimation(MLE) and Generalized Method of Moments(GMM), Learning of Econometric Software: Eviews and Stata.
ECO341A	ECONOMETRICS I		Classical Linear Regression Model (CLRM), Assumptions of the CLRM and its violation, Hypothesis Testing, Gauss Markov Theorem, Properties of the Estimator, Multiple Regression Model, Hetero scedasticity, Autocorrelation and Multicollinearity, Lagged Variables, Dummy Variables, Specification Bias, Simultaneous Equations, Introduction to Time Series, Discrete Choice, Limited Dependent Variable and Panel Data Models, Estimation Procedures Ordinary Least Square(OLS), Generalized Least Squares(GLS), IV(Instrumental Variable), Maximum Likelihood Estimation(MLE) and Generalized Method of Moments(GMM), Learning of Econometric Software: Eviews and Stata.
ECO342	ECONOMETRICS II	3-0-0-0-4	Non Linear Regression Models, Non Parametric Regression Models, Measurement Errors, Stochastic Regressor, Multinomial and Conditional Logit Models, Ordered Logit Models, Nested Logit Models, Random Parameter Models, Truncation, Censoring and Sample Selection Models, Duration and Event Count Models, Dynamic Panel Data Models, Time Series Models including ARCH,GARCH and Multivariate GARCH Models, DEA and Stochastic Frontier Models, Total Factor Productivity Estimation, Levinsohn Petrin Approach of Measurement of Productivity, Single and Multiple Equation GMM Procedures, Application of Econometric Models to Trade,

			Finance, Microeconomics, Development Economics, Growth, Macroeconomics, Industry, among others.
ECO342A	ECONOMETRICS II	3-1-1-0-12	Non Linear Regression Models, Non Parametric Regression Models, Measurement Errors, Stochastic Regressor, Multinomial and Conditional Logit Models, Ordered Logit Models, Nested Logit Models, Random Parameter Models, Truncation, Censoring and Sample Selection Models, Duration and Event Count Models, Dynamic Panel Data Models, Time Series Models including ARCH,GARCH and Multivariate GARCH Models, DEA and Stochastic Frontier Models, Total Factor Productivity Estimation, Levinsohn Petrin Approach of Measurement of Productivity, Single and Multiple Equation GMM Procedures, Application of Econometric Models to Trade, Finance, Microeconomics, Development Economics, Growth, Macroeconomics, Industry, among others.
ECO371A	PUBLIC ECONOMICS AND PUBLIC POLICY	3-0-0-0-0	Unbounded Operators, Matrix representation, Self adjointness Criterion, Quadratic Forms, Differential Operators, Selfadjoint Extensions, Functional Calculus, Spectra of Selfadjoint Operators, Semianalytic vectors, Theorems of Nelson and Nussbaum, States and Observables, Superselection Rules, Position and Momentum, An Uncertainty Principle of Bargmann, Canonical Commutation Relations, Schrodinger representations, Schrodinger Operators, Selfadjointness, A Theorem of Kato, Spectral Theory for Schrodinger Operators, Discrete Spectrum, Essential Spectrum **Course Reference**: 1. N. Akhiezer, I. Glazman, Theory of Linear Operators in Hilbert Space II, Dover, 1961; 2. J. Blank, P. Exner, M. Havlivcek, Hilbert Space Operators in Quantum Physics, Springer, 2008; 3. T. Kato, Perturbation Theory, Springer, 1976; 4. M. Miklavcic, Applied Functional Analysis and Partial Differential Equations, World Scientific, 1998; 4. M. Reed and B. Simon, Methods of Modern Mathematical Physics II, Academic Press, 1975. 24-jul-2014
ECO397A	TECHNICAL COMMUNICATION		TECHNICAL COMMUNICATION
ECO398A	UG PROJECT (UGP-I)		UG PROJECT (UGPI)
ECO399A	UG PROJECT -II	0-0-0-2-9	UG PROJECT II
ECO402	MACROECONOMICS II	3-1-0-0-4	Microeconomic foundations of Macroeconomics, Representative agent model, Application of representative agent model in asset pricing, consumption theoriesetc., Longrun economic growth models, Models of shortrun economic fluctuations, Macroeconomic policy debates validation and application of growth/business cycle models. **Course Reference**: 1. Aghion, A. and Howitt P. The Economics of Growth, MIT Press, 2009; 2. Barro, R. Macroeconomics A Modern Approach, 5th Edition, MIT Press; 3. Mankiw, G. Macroeconomics, 7th Edition, Worth Publishers.
ECO404	HISTORY OF ECONOMIC THOUGHT	3-1-0-0-4	Introduction; Social Choice: How much environmental protection; Market failure: Public bad and externatities; Internalisation of externalities; Regulations: Emission Fees &

			marketable permits; Environmental valuation; Hedonic price method, household production, model & consolouted markets method; Tronsboundary pollotion Sustainable development; Economics of natural resources, Natural resorces accounting; The environmental issues and policies in India.
ECO405	CONTRACT ECONOMICS		Introduction; Economics of contracts (adverse selection and moral hazard); Hidden action, monitoring, and control; Efficient contracts; Transfer prices; Contingent claims; Principal agent models; Incomplete and incentive contracts; Implicit contracts; Auctions and bidding; Regulation of contracts
ECO407	MONETARY ECONOMICS	3-1-0-0-4	Demand for money; Supply of money; Monetary aggregates; Neutrality of money; Money in a growth model; Money in an OLG model; Central bank goals, targets, and instruments; Time consistent versus discretionary policies; Credible monetary policy
ECO408	ADVANCED MACRO ECONOMICS	3-1-0-0-4	Introduction; The Solow growth model; Infinite horizon and overlapping generation models; New growth theory; Realbusiness cycle theory; Traditional Keynesian theories of fluctuations; Incomplete nominal adjustment; Consumption andinvestment; Search frictions and unemployment; Inflation and monetary policy; Budget deficits and fiscal policy
ECO408A	ADVANCED MACRO ECONOMICS	3-0-0-0-9	Introduction; The Solow growth model; Infinitehorizon and overlapping generation models; New growth theory; Real businesscycle theory; Traditional Keynesian theories of fluctuations; Incomplete nominal adjustment; Consumption and investment; Search frictions and unemployment; Inflation and monetary policy; Budget deficits and fiscal policy 18-SEP-14
ECO411A	INDUSTRIAL ECONOMICS		Introduction: Structure Conduct Performance (SCP) paradigm, Chicago School view, modem developments and relevance of industrial policy; Monopoly Power and Industrial Concentration; Oligopolistic Industries: competition in quantities and in prices, cartels and collusion; Strategic Behavior: firm entry, accommodation and exit, barriers to entry, predatory pricing and limit pricing; Empirical Studies of SCP Paradigm
ECO412A	INTERNATIONAL ECONOMICS AND FINANCE		World Trade and Empirical Facts of International Trade with its Explanations, Neoclassical Trade Theories, Alternative and New Trade Theories, Trade PolicyInstruments and their Impact on Welfare, Trade and Income Distribution, International Factor Movements, Negotiations at the GATT and the WTO, Exchange Rate Movements, Past andPresent Arrangements of the International Monetary System including discussion on theEuropean Monetary System and Optimum Currency Area, Regional Trade Agreements, TradeCreation and Trade Diversion, Theories of Exchange Rate and BOP(Balance of Payments) and Different Approaches to the BOP.
ECO413	INDIAN ECONOMIC PROBLEMS		Social accounting matrix; Leontiefs open and closed IO models; Multipliers and linkages in the IO model; Organization of basic data for IO models; Identification of the key sectors; Role of project in development planning; Project development cycles; Capital budgeting decisions; Commercial profit vs. social profitabilityanalysis; Methods of measurement of benefits and costs of projects; Case studies

ECO413A	INDIAN ECONOMIC PROBLEMS	3-0-0-0-9	India in a Global Perspective (broad comparison with developed, developing and emerging economies), Trends in Aggregate Economic Activities (trends in Indian national income and related variables, primary, secondary and service sector growth etc), Agriculture (Green Revolution, productivity, land reforms, farming methods etc), Industry (industrial policy resolutions, growth, industrial bottlenecks, structural reforms etc), and Infrastructure (education, poverty alleviation programmes, energy, transport etc)
ECO422	ECONOMICS OF REGULATION AND IPR		Introduction; Rationale for regulation and antitrust; Regulatory practices, rulesvs. implementation agencies; Regulatory capture; Discriminatory pricing; Controlling franchises; Public enterprise regulation; Restructuring and deregulation of keysectors such as energy, transport etc.; Externalities, environmental concerns,and controls; Product quality, safety, and health issues; Patents; Copyrights;Trademark and Service Mark; Industrial Designs Registration; Protection ofLayout of Designs Integrated Circuit; Protection of New Plant Varieties; AntitrustPolicy and IPR; Agreements and IPR Linkages; Litigation; Continuous Issues inIPR (Such as Biotechnology and IPR, TRIPS and Access to Medicines, etc.).
ECO423	FINANCIAL ECONOMICS	3-1-0-0-4	Basic accounting principles; Basics of financial markets; Return, risk and riskaversion; How securities are traded?; Mutual funds and the institutional environment; Portfolio selection; The capital asset pricing model; Index models and the arbitrage pricing theory; Empirical evidence of market returns; Market efficiency; Bond prices and yields; The term structure of interest rates; Managing bond portfolio; Security analysis; Options and other derivatives; Option valuation;Futures and forward markets; Portfolio management techniques
ECO423A	FINANCIAL ECONOMICS	3-0-0-0-9	Basic accounting principles; Basics of financial markets; Return, risk and risk aversion; How securities are traded?; Mutual funds and the institutional environment; Portfolio selection; The capital asset pricing model; Index models and the arbitrage pricing theory; Empirical evidence of market returns; Market efficiency; Bond prices and yields; The term structure of interest rates; Managing bond portfolio; Security analysis; Options and other derivatives; Option valuation;Futures and forward markets; Portfolio management techniques
ECO424	ECONOMIC ANALYSIS OF LAW	3-1-0-0-4	Introduction to economic analysis of law; Economic theory of property law; Contracts and warranties; and Economic theory of tort law in addition, Thecourse focuses on any are of the following madule(s): Economic crimes and penalties; Economic theory of administrative law; Corporations and corporate finance; Economic analysis of labor law; Economic analysis of competition law; Project assignment
ECO424A	ECONOMIC ANALYSIS OF LAW	3-0-0-0-9	Introduction to economic analysis of law; Economic theory of property law; Contracts and warranties; and Economic theory of tort law in addition, Thecourse focuses on any are of the following madule(s): Economic crimes andpenalties; Economic theory of administrative law; Corporations and corporate finance; Economic analysis of labor law; Economic analysis of competition law; Project assignment

ECO434	INTERNATIONAL ECONOMICS		Global trade in goods and services; Why study international trade and finance;Growth and trade; Basic theory of international trade; Theory of comparative advantage; Implications of HeckserOhlin theory; Alternative theories of trade;Empiricial Tests of Trade Therics; International trade and technical change;Economics of import tariff; Nontariff import barriers; Arguments for and against protection; Regional trading blocks; Trade policies for development; International factor movements; Exchange rate and open economy; Internal and External Balance with Fixed and Flexible Exchange rate; Foreign exchange markets and exchange rates; Balance of payments; International monetary system; Benefits and costs of the Globalication Process.
ECO498A	UNDER GRADUATE PROJECT-III		UG PROJECT (UGPIII)
ECO501	ENVIRONMENTAL ECONOMICS AND POLICY	3-1-0-0-4	(Basic Mathematical Logic; Set Theory; Review of Functions of a Single Variable and Its Application in Economics: Choice, Utility and Aggregation; Functions of Several Variables: Level Curves, Homogeneity and Homotheticity, Concavity and Convexity; Static Optimization: Unconstrained Optimization, Constrained Optimization with Equality and Inequality Constraints; The Envelope Theorem and Duality; Dynamics and Dynamic Optimization. **Course Reference**: 1. Shyam Divan & Armin Rosencranz, Environmental Law and Policy in India, Oxford University Press; 2. R Rajagopalan, Environmental Studies, Oxford University Press; 3. Charles D. Kolstad, Environmental Economics, Oxford University Press; 4. Trade and Environment, by Hiiksn Nordstrom & Scott Vaughan, WTO; 5. Natural Resource and Environmental Economics, Roger Perman, Yue Ma, JamesMcGilvray, and Michael Common; 6. Environmental Economics for three Huggers and other Skeptics, William K. Jaeger; 7. Renewable Resources: The Fishery and Wildlife, David Pearce; 8. Renewable Resources: The Tropical Forest, David Pearce; 9. Economic Theory of Exhaustible Resource: R Ranganathan; 10. Environmental Economics: Hartwick & Olewaler
ECO501A	ENVIRONMENTAL ECONOMICS AND POLICY	3-0-0-0-9	Price mechanism and its limitations to mitigate externalities, economic instruments to promote sustainable development, missing market methods to set market prices for environmental goods and services, renewable and nonrenewable resources and environmental policy. **Course Reference**: 1. Shyam Divan & Armin Rosencranz, Environmental Law and Policy in India, Oxford University Press; 2. R Rajagopalan, Environmental Studies, Oxford University Press; 3. Charles D. Kolstad, Environmental Economics, Oxford University Press; 4. Trade and Environment, by Hiiksn Nordstrom & Scott Vaughan, WTO; 5. Natural Resource and Environmental Economics, Roger Perman, Yue Ma, JamesMcGilvray, and Michael Common; 6. Environmental Economics for three Huggers and other Skeptics, William K. Jaeger; 7. Renewable Resources: The Fishery and Wildlife, David Pearce; 8. Renewable Resources: The Tropical Forest,

			David Pearce; 9. Economic Theory of Exhaustible Resource: R Ranganathan; 10. Environmental Economics: Hartwick & Olewaler
ECO502	APPLIED GAME THEORY		Introduction: Optimal contracts under uncertainty, hidden information (adverse selection), or hidden action (moral hazard); Bilateral contracting: Hiddeninformation screening and signaling, hidden action moral hazard; Optimal contracting with multilateral asymmetric information: Auctions and trade under multilateral private information; moral hazard in teams, tournaments and organizations; Incomplete contracts: Institution design, implementation theory, bilateral and multilateral contracts **Course Reference**: 1. Patrick Bolton and Mathias Dewatripont, Contract Theory (2005), The MIT Press; 2. T.V. S. Rammohan Rao, Contract Economics (2004), New Age International.
ECO502A	APPLIED GAME THEORY	3-0-0-0-9	Introduction: Optimal contracts under uncertainty, hidden information (adverse selection), or hidden action (moral hazard); Bilateral contracting: Hidden information screening and signaling, hidden action moral hazard; Optimal contracting with multilateral asymmetric information: Auctions and trade under multilateral private information; moral hazard in teams, tournaments and organizations; Incomplete contracts: Institution design, implementation theory, bilateral and multilateral contracts **Course Reference**: 1. Patrick Bolton and Mathias Dewatripont, Contract Theory (2005), The MIT Press; 2. T.V. S. Rammohan Rao, Contract Economics (2004), New Age International.
ECO514	INPUT-OUTPUT TECHNIQUES	3-1-0-0-4	Basic inputoutput system; Projection of inputoutput coefficients; Non surveyand partial survey methods; Input demand functions; Capital coefficients and dynamic considerations in input output analysis; Application of inputoutput techniques in the economic planning; Input output tables for the Indian economy; Application of IO models in the field of energy and environment
ECO522A	MONETARY ECONOMICS	3-0-0-0-9	Monetary Policy in the Basic Macro Model, Demand for Money, Targets versus Instruments, Role of Expectations and Monetary Policy, Time versus Discretionary Policy, Credibility of the Central Bank, Theories of Monetary Aggregate, Money in a Growth Model, and Money in an Overlapping Generations Model. **Course Reference**: 1. Monetary Economics by J Handa; 2. Handbook of Monetary Economics, edited by Benjamin Friedman and F H Hahn, Vols 1&2; 3. Journal articles to be suggested in class.
ECO524A	HETEROGENOUS FIRMS AND INTERNATIONAL TRADE	3-0-0-0-9	Static representative agent model, Dynamic representative model, Bellmao equation! Pontryagin's Maximum Principle, Asset pricing, Dynamic endowment economy, Overlapping generations model, Real business cycle models. **Course Reference**: 1. Cooley, T. 1995. Frontiers of Business Cycle Research, Princeton University Press; 2. Krueger, Dirk, Lecture Notes (available on his website); 3. Ljungqvist, L. and Sargent, Thomas J. 2004. Recursive Macroeconomic Theory, SecondEdition, MIT Press, Cambridge, MA; 4. Romer, David. 2006, Advanced Macroeconomics, Third Edition, New York: McGrawHill; 5. Williamson, Stephen D., Lectures in

			Macroeconomics (available on his website).
ECO527	MULTINATIONAL ENTERPRISES	3-1-0-0-4	Introduction; Foreign direct versus portfolio investment; Global and regional trends in direct investment; Horizontal and vertical integration; Ownership location internalization framework; Endogenous market structures in international trade; General equilibrium approaches to the multinational firm; Determinants of FDI; Overseas investment and firm exports; Vertical multinationals,fragmentation and outsourcing; Licensing versus direct investment: models of internalization of the multinational enterprise; Contracts, intellectual property rights, and multinational investment in developing countries; Multinational firms,technology diffusion and trade; International taxation and transfer prices; Dodomestic firms benefit from direct foreign investment?; MNEs and host country relations.
ECO535	PUBLIC ECONOMICS		Scope of public economics; Equity, social welfare and taxation; Taxation, income support and social insurance; Taxation and individuals; Market failure andgovernment intervention; Optimal provision of public goods; Public expenditure and public debt; Modeling government behavior; Organization of public sector
ECO535A	PUBLIC ECONOMICS	3-0-0-0-9	Scope of public economics; Equity, social welfare and taxation; Taxation, income support and social insurance; Taxation and individuals; Market failure and government intervention; Optimal provision of public goods; Public expenditure and public debt; Modeling government behaviour; Organization of public sector.
ECO541	EMPIRICAL METHODS IN APPLIED MICROECONOMICS	3-0-0-0-4	Correlation vs Causality, Omitted Variables, Measurement Error, Randomized Experiments, Introduction to the course; Random Variable, Probability Review. Observational Studies and Regression, Overview of research design, and examples. Measurement Error and Omitted Variables Bias, Applications. Experimental Designs, Applications. Quasi Experimental Designs, Applications. Selection on Observables: Matching and Propensity Scores, Applications. Selection on Observables: Fixed Effects, PrePost Designs and Difference in Differences, Applications. Regression Discontinuity, Applications. Instrumental Variables, Applications. Recent Developments in the field: Discussion of papers on new methods and applications. **Course Reference**: 1. Joshua D. Angrist, JornSteffen Pischke, Mostly Harmless Econometrics: An Empiricist's Companion, Princeton University Press, 2008A; 2. Colin Cameron, Pravin K. Trivedi, Microeconometrics: Methods and Applications Papers from various Journals like American Economic Review, Journal of Political Economy, Quarterly Journal of Economics, Journal of Labor Economics, Journal of development Economics etc. 18-SEP-14
ECO541A	EMPIRICAL METHODS IN APPLIED MICROECONOMICS	3-0-0-0-9	Correlation vs Causality, Omitted Variables, Measurement Error, Randomized Experiments, Introduction to the course; Random Variable, Probability Review. Observational Studies and Regression, Overview of research design, and examples. Measurement Error and Omitted Variables Bias, Applications. Experimental Designs, Applications. Quasi Experimental Designs, Applications. Selection on Observables: Matching and Propensity Scores, Applications. Selection on Observables:

			Fixed Effects, PrePost Designs and Difference in Differences, Applications. Regression Discontinuity, Applications. Instrumental Variables, Applications. Recent Developments in the field: Discussion of papers on new methods and applications. **Course Reference**: 1. Joshua D. Angrist, JornSteffen Pischke, Mostly Harmless Econometrics: An Empiricist's Companion, Princeton University Press, 2008; 2. Colin Cameron, Pravin K. Trivedi, Microeconometrics: Methods and Applications Papers from various Journals like American Economic Review, Journal of Political Economy, Quarterly Journal of Economics, Journal of Labor Economics, Journal of development Economics etc.
ECO542	PANEL DATA PROCEDURES AND ANALYSIS	3-0-3-0-4	1.Panel Data Basics(06) Fixed, Random effect models(one way and two way models),Pooled OLS, Models with unobservable heterogeneity; 2.Model Specification(03) Goodnessoffit measures ,FTest, LMTest, HausmanTest, Model extensions; 3.Dynamic panel data procedures(07) Instrumental Variable Procedure(IV),GIVE(Generalized Instrumental Variable Estimators (2Stage Least Squares) and GMM(Generalized Method of Moments) Estimators, Properties of the GMM estimators, Variances of the IV and 2SLS estimators, Tests for Over identifying Restrictions, Arellano Bond, Arellano Bover , Blundell Bond Procedures, GMM procedure in a simultaneous equation settings; 4.Specification of Dynamic Models(05) SarganHansenTest, Test for autocorrelation, Choice of instruments ,Identification problems; 5.UnitRootTests for Panel Data(04) Levin/Lin, Im/Peseran/Shin, Maddala/Lin ,PANIC Analysis Taking contemporary correlation into account ,Residual tests by Pedroni and Kao TraceTest by LLL (1999); 6.Estimating Cointegration Relationships(04) Fully Modified(FM)OLS (Pedroni, Phillips/Moon), Dynamic Ordinary Least Squares(DOLS)Estimation, Parametric estimation (Pooled Mean Group, 2 Stage Least Squares) ,Estimation of error correction models, Panel VAR(Vector Auto Regression) and Innovation Accounting in a panel framework; 7.Limited Dependent variable models with Panel data(06)Tobit, Logit and Probit Models in a panel settings with applications in Labour economics; 8.Application of Panel data in Trade, Finance, Industrial Economics, Macroeconomics and Microeconomics, among others with hands on experience of doing panel data analysis through standard econometric softwares (07) **Course Reference**: 1.Angrist,J D and JS Pischke, Mostly Harmless Econometrics: An Empiricist Companion, Princeton University Press, Princeton and Oxford,2009; 2.Arellano, M. (2003), Panel Data Econometrics, 1st edition, Oxford University Press, ISBN13: 9780199245291; 3.Baltagi, B.H. (2008), Econometric Analysis of Panel Data, 4th edition, Wiley, ISBN13: 9780470518861; 4.Baltagi, B.H. (2011), Econometrics, 5th edition, Springer, ISBN13: 9783642200588; 5.Cameron, A.C. and Trivedi, P.K. (2010), Microeconometrics Using Stata, 2nd edition, Stata Press, ISBN13: 9781597180733; 6.Greene, W.H. (2011), Econometric Analysis, 7th edition, Prentice Hall, ISBN13: 9780131395381; 7.Verbeek, M. (2012), A Guide to Modern Econometrics, 4th edition, Wiley, ISBN13:

			9781119951674; 8.Wooldridge, J.M. (2010), Econometric Analysis of Cross Section and Panel Data, 2nd edition, The MIT Press, ISBN13: 9780262232586; 9. Christopher Dougherty(2011), Introduction to Econometrics, OUP, Fourth Edition, Oxford, New York
ECO543	BAYESIAN DATA ANALYSIS	3-0-3-0-4	Course Description: This is an introductory level course in Bayesian methods aimed to introduce students to the Bayesian framework (originating from Bayes rule), that formally allows to incorporate nonsample information into the model. The course will equip the students with sufficient tools to analyze data using Bayesian techniques that will be useful in academia as well as industry. The course is targeted for advanced undergraduate students or any individual seeking to learn Bayesian techniques. The course will be heavily dependent on basic knowledge of statistics, elementary calculus, linear algebra, different kind of distributions and linear regression. Consequently, students who have taken the course Econometric Methods (ECO341A) will have an advantage. However, students who are willing to take this course but have not taken econometric methods are required to thoroughly study Ch 1 to Ch 4 from Statistical Inference (by Casella and Berger) and linear regression. Softwares: Bayesian methods are highly computational, hence proficiency in coding is required or one should be willing to put in extra hours to code programs. The official software for this course will be Matlab.
ECO543A	BAYESIAN DATA ANALYSIS	3-0-3-0-9	Course Description: This is an introductory level course in Bayesian methods aimed to introduce students to the Bayesian framework (originating from Bayes rule), that formally allows to incorporate nonsample information into the model. The course will equip the students with sufficient tools to analyze data using Bayesian techniques that will be useful in academia as well as industry. The course is targeted for advanced undergraduate students or any individual seeking to learn Bayesian techniques. The course will be heavily dependent on basic knowledge of statistics, elementary calculus, linear algebra, different kind of distributions and linear regression. Consequently, students who have taken the course Econometric Methods (ECO341A) will have an advantage. However, students who are willing to take this course but have not taken econometric methods are required to thoroughly study Ch 1 to ch 4 from Statistical Inference (by Casella and Berger) and linear regression. Softwares: Bayesian methods are highly computational, hence proficiency in coding is required or one should be willing to put in extra hours to code programs. The official software for this course will be Matlab.
ECO545A	BAYESIAN ECONOMETRIC S		Please see uploaded content file attached.
ECO572	PRODUCTIVITY AND EFFICIENCY ANALYSIS	3-0-0-0-4	This course is designed for students who wish to learn about production economics and benchmarking analysis. Benchmarking is used to measure performance of a producer using a specific indicator (production/ cost/profit) resulting in a metric of performance that is then compared to other producers.

			Students will learn to estimate production and cost functions and compute measures of absolute and relative economic performance using data envelopment analysis (DEA), deterministic frontier analysis (DFA), and stochastic frontier analysis (SFA) methods. Students analyse different types of datasets using software packages such as DEAP, Excel solver, FRONTIER, and Stata. 01-APR-2015
ECO572A	PRODUCTIVITY AND EFFICIENCY ANALYSIS	3-0-0-0-9	This course is designed for students who wish to learn about production economics and benchmarking analysis. Benchmarking is used to measure performance of a producer using a specific indicator (production/ cost/profit) resulting in a metric of performance that is then compared to other producers. Students will learn to estimate production and cost functions and compute measures of absolute and relative economic performance using data envelopment analysis (DEA), deterministic frontier analysis (DFA), and stochastic frontier analysis (SFA) methods. Students analyse different types of datasets using software packages such as DEAP, Excel solver, FRONTIER, and Stata. 01-APR-2015
ECO598	PROJECT-I	0-0-4-0-4	PROJECTI
ECO599	PROJECT-II	0-0-4-0-4	PROJECTII
ECO731	PUBLIC ECONOMICS AND PUBLIC POLICY	3-0-0-0-4	Unbounded Operators, Matrix representation, Self adjointness Criterion, Quadratic Forms, Differential Operators, Selfadjoint Extensions, Functional Calculus, Spectra of Selfadjoint Operators, Semianalytic vectors, Theorems of Nelson and Nussbaum, States and Observables, Superselection Rules, Position and Momentum, An Uncertainty Principle of Bargmann, Canonical Commutation Relations, Schrodinger representations, Schrodinger Operators, Selfadjointness, A Theorem of Kato, Spectral Theory for Schrodinger Operators, Discrete Spectrum, Essential Spectrum **Course Reference**: 1. N. Akhiezer, I. Glazman, Theory of Linear Operators in Hilbert Space II, Dover, 1961; 2. J. Blank, P. Exner, M. Havlivcek, Hilbert Space Operators in Quantum Physics, Springer, 2008; 3. T. Kato, Perturbation Theory, Springer, 1976; 4. M. Miklavcic, Applied Functional Analysis and Partial Differential Equations, World Scientific, 1998; 5. M. Reed and B. Simon, Methods of Modern Mathematical Physics II, Academic Press, 1975.
ECO731A	PUBLIC ECONOMICS AND PUBLIC POLICY	3-0-0-0-9	Unbounded Operators, Matrix representation, Self adjointness Criterion, Quadratic Forms, Differential Operators, Selfadjoint Extensions, Functional Calculus, Spectra of Self adjoint Operators, Semianalytic vectors, Theorems of Nelson and Nussbaum, States and Observables, Superselection Rules, Position and Momentum, An Uncertainty Principle of Bargmann, Canonical Commutation Relations, Schrodinger representations, Schrodinger Operators, Self adjointness, A Theorem of Kato, Spectral Theory for Schrodinger Operators, Discrete Spectrum, Essential Spectrum. **Course Reference**: 1. N. Akhiezer, I. Glazman, Theory of Linear Operators in Hilbert Space II, Dover, 1961; 2. J. Blank, P. Exner, M. Havlivcek, Hilbert Space Operators in Quantum

			Physics, Springer, 2008; 3. T. Kato, Perturbation Theory, Springer, 1976; 4. M. Miklavcic, Applied Functional Analysis and Partial Differential Equations, World Scientific, 1998; 5. M. Reed and B. Simon, Methods of Modern Mathematical Physics II, Academic Press, 1975.
ECO732	ECONOMETRIC S	3-0-1--4	Problems of statistical inference in economics constraints on the parameterspace, random coefficient models, distributed lags, decision models, and systemsof equations. New functional forms kernel estimation, neural networks.
ECO732A	ECONOMETRIC S	3-0-0-0-9	Problems of statistical inference in economics constraints on the parameterspace, random coefficient models, distributed lags, decision models, and systemsof equations. New functional forms kernel estimation, neural networks.
ECO734	INDUSTRIAL ORGANISATION AND POLICY	3-0-0--4	Scope of Industrial organization; Industrial Efficiency; Basic Framework forthe Study of Industrial Organization; Recent Approaches to Industrial Organization; Market Structure and Its Elements; Market Conduct, Internal Structure of theFirm. Critical Appraisal of Industrial Development policies in India; Case Studiesfrom Heavy Industries, Consumer Goods Industries and Public Utilities.
ECO734A	INDUSTRIAL ORGANISATION AND POLICY	3-0-0-0-9	Scope of Industrial organization; Industrial Efficiency; Basic Framework forthe Study of Industrial Organization; Recent Approaches to Industrial Organization; Market Structure and Its Elements; Market Conduct, Internal Structure of theFirm. Critical Appraisal of Industrial Development policies in India; Case Studiesfrom Heavy Industries, Consumer Goods Industries and Public Utilities.
ECO735	DEVELOPMENT ECONOMICS	3-0-0--4	The international trends in economic development, various development theoriesand operational strategies towards capital formation, international capital flows, foreign trade, agriculture, industry, HRD, technology transfer and environmentwill constitute the broad contents of this course. Further, focus will be on new economic policies and emerging new international structures. Besides, theshidents will undertake some empirical project as group assign many.
ECO735A	DEVELOPMENT ECONOMICS	3-0-0-0-9	The international trends in economic development, various development theories and operational strategies towards capital formation, international capital flows, foreign trade, agriculture, industry, HRD, technology transfer and environment will constitute the broad contents of this course. Further, focus will be on new economic policies and emerging new international structures. Besides, the shidents will undertake some empirical project as group assign many.
ECO736	APPLIED ECONOMETRIC S	3-0-0--4	This course provides a methodology of emprical research in applying econometric tools for policy-oriented research in social sciences. Emphasis will be given tovarious ways of handling problems faced in doing empirical research in India.
ECO737	ADVANCES IN MICROECONOM IC THEORY	3-0-0--4	Developments in monopolistic competition (nonprice decisions in particular), the microeconomic theory of modern organiszations (discretionary managerial behaviour, the organizational dimension) as envisaged by Williamson and Coase, and their implications for industrial policy.

ECO737A	ADVANCES IN MICROECONOM IC THEORY	3-0-0-0-9	Developments in monopolistic competition (nonprice decisions in particular), the microeconomic theory of modern organizations (discretionary managerial behaviour, the organizational dimension) as envisaged by Williamson and Coase, and their implications for industrial policy.
ECO738	INTER-INDUSTRY ECONOMICS	3-0-0--4	The course will highlight the basic inputoutput models and their extensions. Various examples would be drawn from the empirical analysis of the inputoutputframework in India and abroad.
ECO738A	INTER-INDUSTRY ECONOMICS	3-0-0-0-9	The course will highlight the basic inputoutput models and their extensions Various examples would be drawn from the empirical analysis of the inputoutpu framework in India and abroad.
ECO740	SEMINAR ON SELECTED TOPICS IN ADVANCED ECONOMIC ANALYSIS	3-0-0--4	The course will cover some frontier topics in advanced economic analysis fora detailed discussion in seminars.
ECO741A	PRODUCTION ECONOMICS		Course Description: This applied course focuses on producer/firm behavior in great detail. This course is designed as a blend of microeconomic theory and quantitative techniques to model production data and answer some important managerial questions. Students will learn to handle production data by means of econometrics and linear programming. In particular, the course will teach how to estimate production, cost, profit, and input demand functions and compute measures of absolute economic performance of a producer. Selected case studies and real life databased assignments will be drawn from various sectors (agriculture, energy, industry etc.).Course Content (Number of lectures 40):Part 1: Theory of firmProduction function, Elasticity of substitution, Elasticity of scale and size, Cost function, Duality between cost and production functions, Profit function, Firms supply function, Total factor productivity (TFP), Index numbers and productivity measurement, Difference between productivity and efficiency.Part 2: Quantitative analysis of production dataData and measurement issues, Flexible forms of production and cost functions, Empirical estimation of production, cost, profit and input demand functions, Testing for functional form: Nested vs. nonnested tests in linear models, JustPope type production function to handle risk in production environment, Formulation of linear programming (LP) problems (primal and dual), Graphical and Simplex solution methods, LP applications in production analysis, Activity analysis. Chambers, **Course Reference**: 1. R.G., Applied Production Analysis: A Dual Approach, Cambridge University Press, 1988; 2. Coelli, T.J., D.S. Prasada Rao, C.J. ODonnell and G.E. Battese, An Introduction to Efficiency and Productivity Analysis, 2nd edition, Springer, New York, 2005; 3. Rasmussen, S., Production Economics, 2nd Edition. Springer, 2013; 4. Articles from American Journal of Agricultural Economics, Journal of Econometrics, and The Review of Economics and Statistics.
ECO742A	EFFICIENCY		Course Descriptions: This applied microeconomics course is

	AND PRODUCTIVITY ANALYSIS		designed for student who wish to learn about benchmarking analysis. Benchmarking is used to measure performance of decision-making unit (here, a producer or a firm) using a specific economic indicator (productions/cost/profit), resulting in a performance metric (e.g. technical efficiency growth) suitable for comparison across similar units. The course offers an introduction to Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). In particular, students will learn to use parametric SFA and nonparametric DEA models to estimate production and most frontiers and compute measures of various types of efficiencies and productivity growth. The course is a mixture of advanced theory, quantitative techniques, and computations involving real life productions data.
ECO745	ADVANCED MONETARY THEORY	3-0-0--4	The course begins with the role of money in static macroeconomic models, neoclassical growth models and consumption loan models, then focusses upon supply of money and monetary aggregate demand for money, and the role ofthe central bank.
ECO745A	ADVANCED MONETARY THEORY	3-0-0-0-9	The course begins with the role of money in static macroeconomic models, neoclassical growth models and consumption loan models, then focusses upon supply of money and monetary aggregate demand for money, and the role ofthe central bank.
ECO747	ENVIRONMENTAL ECONOMICS LEGISLATION AND SOCIAL IMPACT	3-1-0--4	With a view to establish sustainable development and to overcome the dilemma of development, the course proposes to focus on the broad aspects of environmental economics, environmental legislations and the environmental impact assessment. The consequent changes in the approaches and policies ofvarious Government under the leadership of U.N. and World Bank will be discussed along with a number of case studies. The legel aspects of various environmental projects will be discussed. Besides the students will undertake an empirical excercise through project assignment.
ECO747A	ENVIRONMENTAL ECONOMICS LEGISLATION AND SOCIAL IMPACT	3-0-0-0-9	With a view to establish sustainable development and to overcome the dilemma of development, the course proposes to focus on the aspects of environtal economics, environmental legislations and the environmental impact assessment. The consequent chanes in the approaches and policies of various Government under the leadership of U.N. and World Bank will be discussed along with a number of case studies. The legal aspects of various environmental excercise through project assignment.
ECO750	ADVANCED MICROECONOMICS	3-0-0--4	Discussions on macroeconomic theory within the ISLM framework, add the supply considerations, and then review some of the new clasical and new Keynesian contributions; budget financing, interactions with the rest of the world andcommon empirical issues in macroeconomics.
ECO750A	ADVANCED MACROECONOMICS	3-0-0-0-9	Discussions on macroeconomic theory within the ISLM frame work, and the supply considerations, and then review some of the new classical and new keynesian contributions; budget financing, interactions with the rest of the world and common empirical issues in macroeconomics.

ECO751	LAW AND ECONOMICS		Introduction; Economic Analysis of Property Law: An Economic Theory of Property, and Intellectual Property Rights; Economic Analysis of Contrat Law: Economic Theory of Contract, and Economics of Remedies for Breach of Contract; Economic Analysis of Tort Law, and Economics of Tort Liability; Public Law and Economics: Legislative and Executive Participation and Discretion: Economic anaylsis of judicial review, and general Applications to Indian Institutes: Economic theoryof Corporation Law: The Theory of the Firm, Corporation and their Interaction,the Economic Reconstruction of Corporation Law, analysis of Specific Problems of Corporation Law, Economic Analysis of Labour Law: Unions and Productivity,Workers Protective Legislation, Issues in Employment discremination on grounds of Race Sex, and Age; and Economic Analysis of Competition Law: Economic Theory of Competition Law, and Competition Policy in India.
ECO756	PROGRAMME EVALUATION: METHODS AND APPLICATIONS	3-0-0-0-4	Experimental Design, Measurement Error, Omitted Vairables Bias, Quasi_Experimental Designs, Selection on Observables: Matching and Propensity Scores, Difference in Differences, Instrumental Variables, Regression Discontinuity. **Course Reference**: 1. Wooldridge, J.M. (2010), Econometric Analysis of Cross Section and Panel Data, 2nd edition; 2. Cameron, A.C. and Trivedi, P.K. (2005), Microeconometric: Methods and Applications; 3. Cameron A.C. and Trivedi, P.K(2010), Microeconometrics Using Stata, 2nd edition, Stata Press; 4. Angrist, J.D. and J.S. Pischke (2009), Mostly Harmless Exonometrics: An Empiricist Companion; 5. Journal Papers to becrecommended by the Instrucor.
ECO756A	PROGRAMME EVALUATION: METHODS AND APPLICATIONS		Experimental Design, Measurement Error, Omitted Vairables Bias, Quasi Experimental Designs, Selection on Observables: Matching and Propensity Scores, Difference in Differences, Instrumental Variables, Regression Discontinuity. **Course Reference**: 1. Wooldridge, J.M. (2010), Econometric Analysis of Cross Section and Panel Data, 2nd edition; 2. Cameron, A.C. and Trivedi, P.K. (2005), Microeconometric: Methods and Applications; 3. Cameron A.C. and Trivedi, P.K(2010), Microeconometrics Using Stata, 2nd edition, Stata Press; 4. Angrist, J.D. and J.S. Pischke (2009); 5.Mostly Harmless Exonometrics: An Empiricist Companion; 6. Journal Papers to becrecommended by the Instrucor.
ECO799	PHD THESIS		Ph. D. Thesis

ELECTRICAL SCIENCE ENGINEERING

ELECTRICAL ENGINEERING

B.TECH.								Template No. EE-1
	SEMESTER							
	1st	2nd	3rd	4th	5th	6th	7th	8th
C O	MTH101A [11]	MTH102A [11]	COM200 [05]	EE210A [11]	EE320A [11]	DE-1 [09]**	HSS-4 (Level-2) [09]	DE-3 [09]
	PHY101A [03]	PHY103A [11]	EE200A [11]	EE250A [11]	EE330A [11]	DE-2 [09]**	OE-2 [09]	DE-4 [09]
U	PHY102A [11]	CHM101A [03]	ESC201A [14]	ESO203A [13]	EE370A [11]	EE340A [11]	OE-3 [09]	HSS-5 (Level-2) [09]
R	LIF101A [06]	ESC101A [14]	ESO/SO [8]*	HSS-2 (Level-1) [11]	EE380A (Lab) [12]	EE381A [12]	OE-4 [09]	OE-5 [09]
S	ENG112A/HSS-1 (Level-1) [11]	CHM102A [08]	SO-1 [06] (MSO202A)	SO-3 [11] MSO201A	OE-1 [09]	HSS-3 (Level 2) [09]	OE/DE/UGP-3 (EE491A) [09]	OE-6 [09]
E S	PE101A [03]	PE102A [03]	SO-2 [06] (MSO203B)	TA202A [06]	EE390A [02]	OE/DE/UGP-2 (EE392A) [09]	-	UGP-4 [09] (EE492A) (Extra Credits)
	TA101A [09]	-	TA201A [06]	-	UGP-1 [04] (EE391A) (Extra Credits)			-
	54	50	56*	63	56/60	59	45	45/54

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	103	Credits
**Department Elective (DE)	:	36	Credits
Open Elective (OE)	:	54	Credits
*UGP2-3/DE/OE	:	18	Credits
*ESO/ SO	:	44	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	**428**	**Credits**

Basket – A
EE311A [09]
EE321A [09]
EE360A [09]
EE301A [09]

REMARKS:

1) *The open ESO/SO slot may be filled by any ESO/SO course of 8 credits or more.
2) **DE-1 and DE-2 (both) should be selected from Basket-A.
3) *Out of the 18 credits for UGP-2 and UGP-3, only 09 credits may be added as OE credits (where the other 09 may be added as DE credits) OR all 18 credits may be added as DE credits.
4) UGP-1 & UGP-4 are optional and do not count towards degree requirements.
5) UGP-1, 2, 3 and 4 (EE391A, EE392A, EE491A and EE492A) may be taken in any order from the 5th to 8th semester.
6) Upto 36 OE credits may be waived from the minimum requirements for students opting for either Dual Degree or Double Major programme.

BT-MT (PG Part – Category A) *(from the same department)*					Template No.EE-2
C O	7th	8th	SUMMER	9th	10th
U R	DE PG-1 [09]	PG-3 [09]	M.Tech. Thesis [09] (EE699A)	PG-6 [09]	M.Tech. Thesis [36] (EE699A)
S E	DE PG-2 [09]	PG-4 [09] PG-5 [09]	-	M.Tech. Thesis [27] (EE699A)	-
S	18	27	09	36	36

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Component	:	54	Credits
Thesis Component	:	72	Credits

REMARKS:

1) In the 7th semester, in addition to the courses listed above for the PG requirement, students will be expected to complete their UG requirements by taking HSS-4 (level 2), OE-2 and OE-3 (total of 27 credits). In the 8th semester, in addition to the courses listed above for the PG requirements, students will be expected to complete their UG requirements by taking HSS-5 (level 2), DE-3 and OE-5 (total of 27 credits).
2) BT-MT students are NOT permitted to take EE491A (UGP-3) and EE492A (UGP-4) as part of their UG curriculum.
3) Upto 36 credits (from a combination of OE, DE, UGP2-3/DE/OE credits as listed in the BT template minimum requirements) may be used to fulfil requirements for the BT-MT dual degree programme. These will be waived from the BT programme and counted towards PG requirements. The total minimum BT-MT dual degree (category A) credit requirement will be 518.
4) PG-3, 4, 5 & 6 are to be taken with the permission of thesis supervisor.

DOUBLE MAJOR		Template No. EE-3
COURSES	Odd Semester	Even Semester
	Pre-Requisites	
	ESO203A [13]	MSO201A [11]
	MSO202a [06]	
	MSO203b [06]	
	Mandatory EE Courses	
	EE200A [11]	EE210 / EE250 [11]
	EE320A [11]	Any ONE combination from Basket – B [33-41]
	EE330A [11]	EE DE PG [09] (optional)
	EE370A [11]	-
	EE380A [12]/ EE480A [10]	
	EE DE PG [09] / EE391A [04] / EE492A [09] (Optional)	
	-	
	54-65	44-61

TOTAL MANDATORY CREDITS FOR SECOND MAJOR IN ELECTRICAL ENGINEERING: 98 CREDITS

REMARKS:

1) All PG courses should be taken in consultation with the EE DUGC.
2) Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.

Basket – A

EE321A [09]
EE301A [09]
EE340A [11]
EE311A [09]
EE360A [09]
EE381 [12]/
EE481 [06]

Basket – B

1. 3 PG Courses + 1 Course from Basket – A
2. 2 PG Courses + 2 Courses from Basket – A
3. 1 PG Course + 3 Courses from Basket – A
4. 1 PG Course + 2 Course from Basket – A + UGP-3 (EE491A)
5. 2 PG Courses + 1 Course from Basket – A + UGP-3 (EE491A)

MINOR					Template No.EE-4
Title	MICROELECTRONICS/ DIGITAL SYSTEMS	POWER	COMMUNICATIONS & SIGNAL PROCESSING	CONTROLS	RF & PHOTONICS
COURSES	EE200A [11]	EE200A [11]	EE200A [11]	EE200A [11]	EE200A [11]
	EE210A [11]	EE330A [11]	EE320A [11]	EE250A [11]	EE340A [11]
	EE311A [09]/ EE370A [11]	EE360A [09]	EE321A [09]/ EE301A [09]	EE650A [09]	EE612A [09]/ EE642A [09]/ EE648A [09]
	31/33	31	31	31	31

DEPARTMENT OF EE			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
EE200	SIGNALS, SYSTEMS AND NETWORKS	3-1-0-0-4	Continuous and discrete time signals; Fourier series, Fourier, Laplace and Z transform techniques; DFT. Sampling Theorem. LTI systems: I/O description, impulse response and system functions, pole/ zero plots, FIR and IIR systems. Analog and digital filters. Networks: topological description, network theorems, Twoport analysis.
EE200A	SIGNALS, SYSTEMS & NETWORKS	3-1-0-0-11	Continuous and discrete time signals; Fourier series, Fourier, Laplace and Z transform techniques; DFT. Sampling Theorem. LTI systems: I/O description, impulse response and system functions, pole/ zero plots, FIR and IIR systems. Analog and digital filters. Networks: topological description, network theorems, Two port analysis.

EE210	MICROELECTRONICS-I	3-1-0-0-4	1. 1V Characteristics and Large and SmallSignal Models of Diodes, BJTs, and MOSFETs; 2. Biasing; 3. Amplifiers; 4. Output Stages; 5. Frequency Response; 6. Feedback Amplifiers; 7. Stability and Compensation; 8. Operational Amplifier. **Course Reference**: 1. Analysis and Design of Analog Integrated Circuits; P.R. Gray, P.J. Hurst, S.H. Lewis, and R.G. Meyer; Jolm Wiley & Sons, 4th Edition, 2001; 2. MOS Analog Circuits for Signal Processing; R. Gregorian and G.C. Ternes; John Wiley & Sons, 1986; 3. Microelectronic Circuits; A.S. Sedra and K.C. Smith; Oxford University Press, 5th Edition,2004; 4. Microelectronics; J. Milbnan and A. Grabel; McGrawHill, 2nd Edition, 1987.
EE210A	MICROELECTRONICS-I	3-1-0-0-11	1. 1V Characteristics and Large and SmallSignal Models of Diodes, BJTs, and MOSFETs; 2. Biasing; 3. Amplifiers; 4. Output Stages; 5. Frequency Response; 6. Feedback Amplifiers; 7. Stability and Compensation; 8. Operational Amplifier. **Course Reference**: 1. Analysis and Design of Analog Integrated Circuits; P.R. Gray, P.J. Hurst, S.H. Lewis, andR.G. Meyer; Jolm Wiley & Sons, 4th Edition, 2001; 2. MOS Analog Circuits for Signal Processing; R. Gregorian and G.C. Ternes; John Wiley & Sons, 1986; 3. Microelectronic Circuits; A.S. Sedra and K.C. Smith; Oxford University Press, 5th Edition,2004; 4. Microelectronics; J. Milbnan and A. Grabel; McGrawHill, 2nd Edition, 1987.
EE250	CONTROL SYSTEMS ANALYSIS	3-1-0-0-4	Negative feedback control systems, Linear time invariant dyanamic systems, Mason's gain formula, transfer function, frequency and time domain analysis, performance analysis, Nyquist stability criterion. Bode plots, Root locus. Feedback system design using Bode plotsand root locus. PID control. Nonlinear systems, circle criterion, anti windup schemes. Statespace models.
EE250A	CONTROL SYSTEMS ANALYSIS	3-1-0-0-11	Negative feedback control systems, Linear time invariant dyanamic systems, Mason's gainformula, transfer function, frequency and time domain analysis, performance analysis, Nyquist stability criterion. Bode plots, Root locus. Feedback system design using Bode plotsand root locus. PID control. Nonlinear systems, circle criterion, anti windup schemes. Statespace models.
EE301	DIGITAL SIGNAL PROCESSING	3-0-0-0-4	Sampling and Reconstruction of continuous time signals, Characterization and properties of discrete time signals and systems, Computation of the discrete time Fourier transform andits properties, Computation of the discrete Fourier transform and its properties, Fast Fourier transform algorithms, The Ztransform and its properties, Transform analysis of linear timeinvariant systems, Implementation of structures for discrete time systems, Digital filter design techniques, Homomorphic filtering, Applications of DSP in speech and image processing. 1. DiscreteTime Signal Processing (Second Edition), Alan V. Oppenheim, Ronald W. Schafer, and John R. Buck, Pearson Education India
EE301A	DIGITAL SIGNAL PROCESSING	3-0-0-0-9	Sampling and Reconstruction of continuous time signals, Characterization and properties of discrete time signals and systems, Computation of the discrete time Fourier transform

			andits properties, Computation of the discrete Fourier transform and its properties, Fast Fourier transform algorithms, The Ztransform and its properties, Transform analysis of linear time invariant systems, Implementation of structures for discrete time systems, Digital filter design techniques, Homomorphic filtering, Applications of DSP in speech and image processing. **Course Reference**: 1. DiscreteTime Signal Processing (Second Edition), Alan V. Oppenheim, Ronald W. Schafer, and John R. Buck, Pearson Education India
EE311	MICROELECTRONICS II	3-0-0-0-4	1. Semiconductors and Crystal Structures; 2. Basic Semiconductor Physics EE311; 3. Excess Carriers and Transport Processes in Semiconductors; 4. Junction Diode; 5. Bipolar Junction Transistor (BJT); 6. MOS Capacitor (MOSCAP); 7. MetalOxideSemiconductor FieldEffect Transistor (MOSFET); 8. Some Important Devices Tunnel Diode, Varactor Diode, Light Emitting Diode (LED), Photodetector, and Solar Cell **Course Reference**: 1. Solid State Electronic Devices, B.G. Streetman arid S. Banerjee, Prentice Hall, 2000; 2. Device Electronics for Integrated Circuits, R.S. Muller and T.I. Kamins, John Wiley, 2003; 3. Introduction to Semiconductor Materials and Devices, M.S. Tyagi, John Wiley, 1991; 4. Physics of Semiconductor Devices, M. Shur, Prentice Hall.J 990.
EE311A	MICROELECTRONICS II	3-0-0-0-9	1. Semiconductors and Crystal Structures; 2. Basic Semiconductor PhysicsEE311; 3. Excess Carriers and Transport Processes in Semiconductors; 4. Junction Diode; 5. Bipolar Junction Transistor (BJT); 6. MOS Capacitor (MOSCAP); 7. Metal Oxide Semiconductor FieldEffect Transistor (MOSFET); 8. Some Important Devices Tunnel Diode, Varactor Diode, Light Emitting Diode (LED), Photodetector, and Solar Cell **Course Reference**: 1. Solid State Electronic Devices, B.G. Streetman arid S. Banerjee, Prentice Hall, 2000; 2. Device Electronics for Integrated Circuits, R.S. Muller and T.I. Kamins, John Wiley, 2003; 3. Introduction to Semiconductor Materials and Devices, M.S. Tyagi, John Wiley, 1991; 4. Physics of Semiconductor Devices, M. Shur, Prentice Hall,1990.
EE320	PRINCIPLES OF COMMUNICATIONS	3-1-0-0-4	Fourier transform theory for communication systems, Analog communication systems. Amplitude Modulation, Envelope Detection, Double Sideband (DSB), Single sideband (SSB) and Vestigial Sideband (VSB) systems, Baseband Passband equivalence. Angle Modulation, Frequency Modulation, Phase Modulation, Spectrum of FM signals. Pulse Modulation, Quantization, Compression, Delta and DPCM Modulation. Probability, MAP detection, Random Processes, Strict and Wide Sense Stationarity Ergodicity, AWGN. Digital Communication systems, Optimality of Matched filter, BitError Rate (BER), Signal constellation theory, BPSK and QPSK modulation. GSM/TDMA and IS95/CDMA cellular systems. Statistical Multiplexing and packet switching, ALOHA, slotted ALOHA, Basics of queueing and trunking systems.
EE320A	PRINCIPLES OF COMMUNICATION	3-1-0-0-11	Fourier transform theory for communication systems, Analog communication systems. Amplitude Modulation, Envelope Detection, Double Sideband (DSB), Single sideband (SSB) and Vestigial Sideband (VSB) systems, Baseband Passband

			equivalence. Angle Modulation, Frequency Modulation, Phase Modulation, Spectrum of FM signals. Pulse Modulation, Quantization, Compression, Delta and DPCM Modulation. Probability, MAP detection, Random Processes, Strict and Wide Sense Stationarity Ergodicity, AWGN. Digital Communication systems, Optimality of Matched filter, BitError Rate (BER), Signal constellation theory, BPSK and QPSKmodulation. GSM/TDMA and IS95/CDMA cellular systems. Statistical Multiplexing and packet switching, ALOHA, slotted ALOHA, Basics of queueing and trunking systems.
EE321	COMMUNICATION SYSTEMS	3-0-0-0-4	Information measures. Source coding. ISI & channel equalization, partial response signalling. Mary modulation systems, error probability calculations PLLs and FM threshold extension. Error control coding, block and convolution codes. Combined modulation and coding, trellis coded modulation. Spread spectrum systems.
EE321A	COMMUNICATION SYSTEMS	3-0-0-0-9	Information measures. Source coding. ISI & channel equalization, partial response signalling. Mary modulation systems, error probability calculations. PLLs and FM threshold extension. Error control coding, block and convolution codes. Combined modulation and coding, trellis coded modulation. Spread spectrum systems.
EE330	POWER SYSTEMS	3-1-0-0-4	1. Introduction to power system structure, types of components; 2. Power Calculations, in balanced threephase Circuits, Method of Symmetrical Components forunbalanced threephase Circuits; 3. Different types of transformers and transformer Connections; 4. Inductance and capacitance calculations for transmission lines; 5. Models for short and long transmission lines, steadystate operation, shunt and seriescompensation, transients on transmission lines; 6. Network models of power system using admittance and impedance matrices; 7. The Load flow problem, Equations for bus powers and their numerical solution using Gauss Siedeland Newton Raphson methods; 8. Analysis of faulted power systems using sequence networks; 9. Basic stability analysis, derivation of swing equation ,equal area criteria, calculation of criticalclearing angle, numerical solution of swing equation; 10. Basics ofEconomic operation, incremental fuel cost, allocation ofload between generators ina plant. **Course Reference**: 1. Power System Analysis John J. Grainger & William D Stevenson Jr, McGraw Hill1994; 2. Power System Analysis and design J Duncan Glover, M. Sarma zd edition, PWS PublishingCo Boston 2001; 3. Power System Engineering, D. P Kothari & I.J. Nagrath, Tata McGraw Hill,2008.
EE330A	POWER SYSTEMS	3-1-0-0-11	1. Introduction to power system structure, types of components; 2. Power Calculations, in balanced threephase Circuits, Method of Symmetrical Components forum balanced three phase Circuits; 3. Different types of transformers and transformer Connections; 4. Inductance and capacitance calculations for transmission lines; 5. Models for short and long transmission lines, steady state operation, shunt and series compensation, transients on transmission lines; 6. Network models of power system using admittance and impedance matrices; 7. The Load flow problem, Equations for bus powers and their numerical

			solution using Gauss Siedeland NewtonRaphson methods; 8. Analysis of faulted power systems using sequence networks; 9. Basic stability analysis, derivation of swing equation ,equal area criteria, calculation of criticalclearing angle, numerical solution of swing equation; 10. Basics of Economic operation, incremental fuel cost, allocation ofload between generators ina plant. **Course Reference**: 1. Power System Analysis John J. Grainger & William D. Stevenson Jr, McGraw Hill1994; 2. Power System Analysis and design J. Duncan Glover, M. Sarma zd edition, PWS PublishingCo Boston 2001; 3. Power System Engineering, D.P. Kothari & I.J. Nagrath, Tata McGraw Hill,2008.
EE340	ELECTROMAGNETI C THEORY	3-1-0-0-4	I. Overview of Static Electric and Magnetic Fields, Steady Electric Currents; 2. Time Varying Electromagnetic Fields, Maxwell's Equations, Boundary Conditions; 3. Plane Electromagnetic Waves, Propagation in Free Space and in Matter; 4. Reflection and Refraction of Waves at Conducting and Dielectric Boundary; 5. Transmission Lines: TEM waves, Transmission Line Equations, Wave Propagation along Finite Transmission Lines, Transients on Lines, The Smith Chart; 6. Waveguides, Waves in Guided Media, Parallel Plate Waveguide, Rectangular Waveguide, Cavity Resonators; 7. Basic Theory of Antennas and Radiation Characteristics, Elementary Types of Antennas. **Course Reference**: I. Field and Wave Electromagnetics David K. Cheng, Second Edition, Pearson Education, 2008; 2. Engineering Electromagnetics W A Haytt & J A Buck, Seventh Edition, Tata McGrawHill, 2006; 3. Electromagnetic Waves and Radiating Systems by E. C. Jordan and K. G. Bahnain,Second Edition, Prentice Hall Inc., Tata McGraw Hill; 4. Principles ofE!ectromagnetics Mathhew N.O. Sadiku, Fourth Edition, OxfordUniversity Press; 5. Electromagnetics with Applications Kraus and Fleisch, Fifth Edition, McGraw Hill,1999.
EE340A	ELECTROMAGNETI C THEORY	3-1-0-0-11	I. Overview of Static Electric and Magnetic Fields, Steady Electric Currents; 2. Time Varying Electromagnetic Fields, Maxwell's Equations, Boundary Conditions; 3. Plane Electromagnetic Waves, Propagation in Free Space and in Matter; 4. Reflection and Refraction ofWaves at Conducting and Dielectric Boundary; 5. Transmission Lines: TEM waves, Transmission Line Equations, Wave Propagation alongFinite Transmission Lines, Transients on Lines, The Smith Chart; 6. Waveguides, Waves in Guided Media, Parallel Plate Waveguide, Rectangular Waveguide,Cavity Resonators; 7. Basic Theory of Antennas and Radiation Characteristics, Elementary Types of Antennas. **Course Reference**: 1. Field and Wave Electromagnetics David K. Cheng, Second Edition, Pearson Education, 2008; 2. Engineering Electromagnetics W A Haytt & J A Buck, Seventh Edition, Tata McGrawHill, 2006; 3. Electromagnetic Waves and Radiating Systems by E. C. Jordan and K. G. Bahnain,Second Edition, Prentice Hall Inc., Tata McGraw Hill; 4. Principles of E!ectromagnetics Mathhew N.O. Sadiku, Fourth Edition, Oxford University Press; 5. Electromagnetics with Applications Kraus and Fleisch, Fifth Edition, McGraw Hill,1999.

EE360	POWER ELECTRONICS	3-0-3-0-4	1. Power Electronics components: Switching characteristics of power devices e.g. diodes, thyristors, GTOs, MOS transistors, IGBTs etc; snubber circnits, calculation of switching losses, resonant ZVS and ZCS switching, calculation of device losses, magnetic components, capacitors; 2. Controlled Converters: Basic Single phase and three phase rectifier configurations, various modesof operation, a.c .regulators, and reactive power compensators; 3. Inverters: Basic Single phase and three phase VSI confignrations, modulation techniques forvoltage control, Basic CSI configurations and their operation; 4. DCDC converters: Steadystate and dynamic analysis of Buck, Boost, BuckBoost and Cukconverters, switchmode power supplies.
EE360A	POWER ELECTRONICS	3-0-0-0-9	1. Power Electronics components: Switching characteristics of power devices e.g. diodes, thyristors, GTOs, MOS transistors, IGBTs etc; snubber circnits, calculation of switching losses, resonant ZVS and ZCS switching, calculation of device losses, magnetic components, capacitors; 2. Controlled Converters: Basic Single phase and three phase rectifier configurations, various modesof operation, a.c .regulators, and reactive power compensators; 3. Inverters: Basic Single phase and three phase VSI confignrations, modulation techniques forvoltage control, Basic CSI configurations and their operation; 4. DCDC converters: Steadystate and dynamic analysis of Buck, Boost, BuckBoost and Cukconverters, switchmode power supplies.
EE370	DIGITAL ELECTRONICS & MICROPROCESSOR TECHNOLOGY	3-1-0-0-4	Digital and Analogue, Boolean and Binary Metric for Digital Circuits and Systems Transistors, Inverters, CMOS Inverter Inverter Parameters and design Combinatinal Circuits, Logic Gates, NAND, NOR, XOR Logic Families, Static and Dynamic CMOS Designs Sequential Circuit, Bi stability, Registers, Latches and Flipflop Pipelining Array Based Logic Implementations Memories, Organisation, Cell Designs, Peripherals Digital Systems, CPU Register Transfers and Data Paths Sequencing and Control Instruction Sets Introduction to Microprocessors Introduction to circuit simulators (SPICE) and hardware description languages (HDL) suchas VHDL and Verilog at appropriate places in the course. Software to be used for solving homework assignment problems, including some design problems.
EE370A	DIGITAL ELECTRONICS	3-1-0-0-11	Digital and Analogue, Boolean and Binary Metric for Digital Circuits and Systems Transistors, Inverters, CMOS Inverter Inverter Parameters and design Combinatinal Circuits, Logic Gates, NAND, NOR, XOR Logic Families, Static and Dynamic CMOS Designs Sequential Circuit, Bi stability, Registers, Latches and Flipflop Pipelining Array Based Logic Implementations Memories, Organisation, Cell Designs, Peripherals Digital Systems, CPU Register Transfers and Data Paths Sequencing and Control Instruction Sets Introduction to Microprocessors Introduction to circuit simulators (SPICE) and hardware description languages (HDL) suchas VHDL and Verilog at appropriate places in the course. Software to be used for solving homework assignment problems, including some design problems.
EE380	ELECTRICAL	0-2-6-0-4	Experiments from various areas of Electrical Engineering with

	ENGINEERING LAB I		emphasis on electronic devices, circuits, control systems and machines. This course has three labs: Electronic Circuits Lab. (7 experiments), Control Systems Lab. (6 experiments) and EMEC Lab.(6 experiments)
EE380.	ELECTRICAL ENGINEERING LAB I	0-2-6--4	Experiments from various areas of Electrical Engineering with emphasis on electronic devices, circuits, control systems and machines. This course has three labs: Electronic Circuits Lab. (7 experiments), Control Systems Lab. (6 experiments) and EMEC Lab (6 experiments)
EE380A	ELECTRICAL ENGINEERING LAB I	0-2-6-0-12	Experiments from various areas of Electrical Engineering with emphasis on electronic devices, circuits, control systems and machines. This course has three labs: Electronic Circuits Lab. (7 experiments), Control Systems Lab. (6 experiments) and EMEC Lab (6 experiments)
EE381	ELECTRICAL ENGINEERING LAB II	0-2-6-0-4	Experiments from various areas of Electrical Engineering with emphasis on digital electronics, communication, machines, drives and power systems, and electromagnetics. This course has three labs: Electronic Circuits Lab.II (7 experiments), DCMP Lab. (7 experiments) and EMEC Lab (6 experiments)
EE381A	ELECTRICAL ENGINEERING LABORATORY -II	0-3-6-0-12	Experiments from various areas of Electrical Engineering with emphasis on digital electronics, communication, machines, drives and power systems, and electromagnetics. This course has three labs: Electronic Circuits Lab.II (7 experiments), DCMP Lab. (7 experiments) and EMEC Lab (6 experiments)
EE390A	ELECTRICAL ENGINEERING COMMUNICATION SKILLS	0-0-2-0-2	Technical Communication, definition and attributes. Ethics in communication. Technical Writing. Report and Article composition. How to write a Technical Brochure. Writing summary and abstracts of technical documents. Software tools for technical report writing. Listening Comprehension. Oral Communication and Presentation. Technical Presentation and use of multimedia.
EE392A	UNDER GRADUATE PROJECT II	0-0-0-0-9	UG PROJECT (UGP II)
EE393A	ELECTRICAL ENGINEERING UNDER GRADUATE PROJECT I	0-0-2-0-4	ELECTRICAL ENGINEERING UNDER GRADUATE PROJECT I
EE395A	ELECTRICAL ENGINEERING UNDER GRADUATE PROJECT III	0-0-0-0-9	ELECTRICAL ENGINEERING UNDER GRADUATE PROJECT III
EE399A	ELECTRICAL ENGINEERING COMMUNICATION SKILLS	0-0-0-0-9	ELECTRICAL ENGINEERING COMMUNICATION SKILLS
EE416	OPTO-ELECTRONICS	3-0-0--4	LEDs, semiconductor lasers, modulation of laser sources. Avalanche and PIN photodetectors and their characteristics. Solar cells. Optical fibers and their characteristics. Integrated optics. Fiber optic communication systems, system design consideration.
EE416A	OPTO-	3-0-0-0-9	LEDs, semiconductor lasers, modulation of laser sources.

	ELECTRONICS		Avalanche and PIN photo detectors and their characteristics. Solar cells. Optical fibers and their characteristics. Integrated optics. Fiber optic communication systems, system design consideration.
EE442A	ANTENNAS AND PROPAGATION	3-0-0-0-9	Retarded potential, radiation from current element and dipole, radiation patterns, impedance, reciprocity. Various types of antennas, interferometers and multielement arrays, Antenna Measurements. Ground wave propagation, terrain and earth curvature effects. Tropospheric propagation; fading, diffraction and scattering; Ionospheric Propagation refractive index, critical frequencies, effectsof magnetic field.
EE455	TRANSDUCERSAND INSTRUMENTATION	3-0-0--4	Measurement process; scales of measurement; configuration and functional description of measurement systems; performance characteristics; sensing elements and transducers for measurement of motion, force, pressure, flow, temperature, light, vacuum, etc.; transducer interfacing; signal conditioning transmission and recording; microprocessor - based instrumentation.
EE490.	PROJECT WORK	0-0-0--8	PROJECT WORK
EE491	PROJECT I	0-0-0--3	PROJECT I
EE491A	UNDER GRADUATE PROJECT -III	0-0-0-0-9	UG PROJECT (UGPIII)
EE492	PROJECT II	0-0-0--5	PROJECT II
EE600	MATHEMATICAL STRUCTURES OF SIGNALS & SYSTEMS	3-0-0--4	Nature of definitions; Theory of measurement and scales; Symmetry, invariance and groups; Groups in signals and systems; Algebraic and relational structuresof signal spaces and convolutional systems; Representation theory of groups, harmonic analysis and spectral theory for convolutional systems.
EE600A	MATHEMATICAL STRUCTURES OF SIGNALS & SYSTEMS	3-0-0-0-9	Nature of definitions; Theory of measurement and scales; Symmetry, invariance and groups; Groups in signals and systems; Algebraic and relational structures of signal spaces and convolutional systems; Representation theory of groups, harmonic analysis and spectral theory for convolutional systems.
EE601	MATHEMATICAL METHODS IN SIGNAL PROCESSING	3-0-0--4	Generalized inverses, regularization of illposed problems. Eigen and singular value decompositions, generalized problems. Interpolation and approximation by least squares and minimax error criteria. Optimization techniques for linear and nonlinear problems. Applications in various areas of signal processing.
EE601A	MATHEMATICAL METHODS IN SIGNAL PROCESSING	3-0-0-0-9	Generalized inverses, regularization of illposed problems. Eigen and singular value decompositions, generalized problems. Interpolation and approximation by least squares and minimax error criteria. Optimization techniques for linear and nonlinear problems. Applications in various areas of signal processing.
EE602	STATISTICAL SIGNAL PROCESSING-I	3-0-0--4	Power Spectrum Estimation Parametric and Maximum Entropy Methods, Wiener, Kalman Filtering, Levinson Durban Algorithms Least Square Method, Adaptive Filtering, Nonstationary Signal Analysis, WignerVille Distribution, WaveletAnalysis.
EE602A	STATISTICAL SIGNAL PROCESSING-I	3-0-0-0-9	Power Spectrum Estimation Parametric and Maximum Entropy Methods, Wiener, Kalman Filtering, Levinson Durban Algorithms Least Square Method, Adaptive Filtering, Nonstationary Signal

			Analysis, WignerVille Distribution, Wavelet Analysis.
EE604	IMAGE PROCESSING	3-0-0--4	Human visual system and image perception, monochrome & colour vision models, colour representation; image sampling & quantization; 2D systems; image transforms; image coding; stochastic models for image representation; image enhancement, restoration & reconstruction. Image analysis using multiresolution techniques.
EE604A	IMAGE PROCESSING	3-0-0-0-9	Human visual system and image perception, monochrome & colour vision models, colour representation; image sampling & quantization; 2D systems; image transforms; image coding; stochastic models for image representation; image enhancement, restoration & reconstruction. Image analysis using multiresolution techniques.
EE605	INTRODUCTION TO SIGNAL ANALYSIS	3-0-0--4	Discrete and Continuous time signals and systems, LTI systems, Convolution, Difference equations. Frequency domain representation: Fourier transform andits properties. Random discrete signals. Sampling and reconstruction: Change of sampling rate. Normed vector spaces, basis, linear independence, orthogonality. Linear systems of equations. Over and Under determined systems. Row and Column spaces, Null spaces. Least square and minimum norm solutions. Inverse and pseudo inverse, Symmetry transformations. Eigen vectors and eigenvalues. Hilbert transforms, band pass representations and complex envelope. Base bandpulse transmission, matched filtering, ISI, equalization. Coherent and noncoherent detection.
EE605A	INTRODUCTION TO SIGNAL ANALYSIS	3-0-0-0-9	Discrete and Continuous time signals and systems, LTI systems, Convolution, Difference equations. Frequency domain representation: Fourier transform andits properties. Random discrete signals. Sampling and reconstruction: Changeof sampling rate. Normed vector spaces, basis, linear independence, orthogonality. Linear systems of equations. Over and Under determined systems. Row and Column spaces, Null spaces. Least square and minimum norm solutions. Inverse and pseudo inverse, Symmetry transformations. Eigen vectors and eigenvalues. Hilbert transforms, band pass representations and complex envelope. Base bandpulse transmission, matched filtering, ISI, equalization. Coherent and noncoherent detection.
EE606	ARCHITECTURE AND APPLICATIONS OF DIGITAL SIGNAL PROCESSORS	3-0-3-0-5	DSP Architecture: Von Neumann vs. Harvard architecture, VelociTI architecture Memory management of TI DSP processors C2X, C6X. Peripheral overview of TI C2X, C6X processor. Code Composer Studio (CCS) overview, writing simple programs in assembly, linear assembly and C. Instruction set of TI C2X/C6X processor. Optimization of assembly and C code. Pipelining. General Extension Language (GEL). Assembler, Linker. Interrupts RTDX. DSP/BIOSList of Experiments Introduction to Code Composer Studio1 Introduction to Code Composer Studio11 Introduction to the Addressing Modes FFT and Bit Reversal Operation FFT and its Applications Audio Codec and its Applications Real Time Data Exchange Using Matlab and Labview FIR filtering by interfacing Matlab with Code Composer Studio Introduction to Interrupts Digital communication using Binary Phase Shift Keying Current control of a threephase inverter with passive load Current control

			of a singlephase inverter with passive load PLL for a threephase ac system PLL for a singlephase system Current control of a threephase STA TCOM Speed control of an induction motor by V/f method Rulph Chassaing; Digital Signal Processing And Applications With The C6713 And C6416 DSK. **Course Reference**: 1. Wiley Interscience, 2004. Thad B. Welch, Wright, H.G. Cameron, and Michael G. Morrow; 2.Real Time DigitalSignal Processing from Matlab to C with the TMS320C6x DSK, CRC, 2005; 3. Steven A. Tretter;Communication System Design Using DSP Algorithms:With Laboratory Experiments for the TMS320C6701 and TMS320C6711, Springer, 2003; 4. Nasser Kehtarnavaz, RealTime Digital Signal Processing Based On The TMS320C6000; Newnes Publishers, 2004; 5. Rulph Chassaing, DSP Applications Using C And The TMS320C6x DSK, Wiley Interscience, 2002; 6. Shehrzad Qureshi; Embedded Image Processing On The TMS320C6000 DSP: Examples in Code Composer Studio and MATLAB, Springer, 2006.
EE606A	ARCHITECTURE AND APPLICATIONS OF DIGITAL SIGNAL PROCESSORS	3-0-3-0-5	DSP Architecture: Von Neumann vs. Harvard architecture, Velocity architecture Memory management of TI DSP processors C2X, C6X. Peripheral overview of TI C2X, C6X processor. Code Composer Studio (CCS) overview, writing simple programs in assembly, linear assembly and C. Instruction set of TI C2X/C6X processor. Optimization of assembly and C code. Pipelining. General Extension Language (GEL). Assembler, Linker. Interrupts RTDX. DSP/BIOS. List of Experiments Introduction to Code Composer Studio1. Introduction to Code Composer Studio11. Introduction to the Addressing Modes FFT and Bit Reversal Operation FFT and its Applications. Audio Codec and its Applications. Real Time Data Exchange Using Matlab and Labview FIR filtering by interfacing Matlab with Code Composer Studio. Introduction to Interrupts Digital communication using Binary Phase Shift Keying. Current control of a threephase inverter with passive load. Current control of a singlephase inverter with passive load. PLL for a threephase ac system. PLL for a singlephase system. Current control of a threephase STA TCOM Speed control of an induction motor by V/f method Rulph Chassaing, **Course Reference**: 1.Digital Signal Processing And Applications With The C6713 And C6416 DSK;, WileyInterscience, 2004; 2. Thad B. Welch, Wright, H.G. Cameron, and Michael G. Morrow,Real Time DigitalSignal Processing from Matlab to C with the TMS320C6x DSK;, CRC, 2005; 3. Steven A. Tretter;Communication System Design Using DSP Algorithms:With Laboratory Experiments for the TMS320C6701 and TMS320C671, Springer, 2003; 4. Nasser Kehtarnava; RealTime Digital Signal Processing Based On The TMS320C6000;, Newnes Publishers, 2004; 5. Rulph Chassaing, DSP Applications Using C And The TMS320C6x DSK, Wiley Interscience, 2002; 6. Shehrzad Qureshi;Embedded Image Processing On The TMS320C6000 DSP: Examples in Code Composer Studio and MATLAB, Springer, 2006.
EE607	WAVELET TRANSFORMS FOR SIGNAL & IMAGE	3-0-0--4	Basics of functional Analysis; Basics of Fourier Analysis; Spectral Theory; Time Frequency representations; Nonstationary Processes; Continuous Wavelet Transforms;

	PROCESSING		Discrete Time Frequency Transforms; Multi resolution Analysis; Time Frequency Localization; Signal Processing Applications; Image Processing Applications
EE607A	WAVELET TRANSFORMS FOR SIGNAL & IMAGE PROCESSING	3-0-0-0-9	Basics of functional Analysis; Basics of Fourier Analysis; Spectral Theory; Time Frequency representations; Nonstationary Processes; Continuous Wavelet Transforms; Discrete Time Frequency Transforms; Multi resolution Analysis; Time Frequency Localization; Signal Processing Applications; Image Processing Applications
EE608	DIGITAL VIDEO SIGNAL PROCESSING	3-0-0--4	Representation of digital video including modeling of video image formation, spatiatem poral sampling over lattices, conversion of signals sampled on different lattices and sampling rate conversion of video signals.Twodimensional Motion Estimation: 2D Motion vs Apparent Motion, occlusion/Aperture problems, 2D Motion field Models, optical flow methods; blockbased methods, pelrecursive methods and Bayesian methods.Video filtering: Motion compensated filtering, including spatiatem poral spectrum, filtering along motion trajectories; Nois.e filtering, Video Restoration, including Modeling, Intraframe shift invariant I variant restoration, multiframe restoration; Standards conversion including practical Up/Down conversion Methods.Video compression: Basic concepts and techniques of video coding, Interframe Compression Methods, Video Compression Standards (MPEG2, MPEG4, H.264) Low bit rate Video Codecs,Embedded Video Codecs, Scalable Video coding. **Course Reference**: 1. Image and Video Processing, A.I. Bovik, Elosovier Academic Press, 2005; 2. Digital Pictures A.N. Netravali, B.G. Haskell, Plenum Press, 1997; 3. Digital Video Transcoding; 4. H. Sun, X. Chen and T. Chiang, CRC Press 2005; 5. Digital Video Processing; A. Murat Tekalp, Prentice Hall Signal Processing Series, 1995. 6. Wireless Video Communications; L. Hanzo, P.J. Cherriman, J. Streit, IEEE Series on Digital and Mobile Communication, 2001 .
EE608A	DIGITAL VIDEO SIGNAL PROCESSING	3-0-0-0-9	Representation of digital video including modeling of video image formation, spatiatemporal sampling over lattices, conversion of signals sampled on different lattices and sampling rate conversion of video signals.Two dimensional Motion Estimation: 2D Motion vs Apparent Motion, occlusion/Aperture problems, 2D Motion field Models, optical flow methods; blockbased methods, pelrecursive methods and Bayesian methods.Video filtering: Motion compensated filtering, including spatiatemporal spectrum, filtering along motion trajectories; Nois.e filtering, Video Restoration, including Modeling, Intraframe shift invariant I variant restoration, multiframe restoration; Standards conversion including practical Up/Down conversion Methods.Video compression: Basic concepts and techniques of video coding, Interframe Compression Methods, Video Compression Standards (MPEG2, MPEG4, H.264) Low bit rate Video Codecs,Embedded Video Codecs, Scalable Video coding. **Course Reference**: 1. Image and Video Processing, A.I. Bovik, Elosovier Academic Press, 2005; 2. Digital Pictures A.N. Netravali, B.G. Haskell, Plenum Press, 1997; 3. Digital Video

			Transcoding; H. Sun, X. Chen and T. Chiang, CRC Press 2005; 4. Digital Video Processing A. Murat Tekalp, Prentice Hall Signal Processing Series, 1995; 5. Wireless Video Communications; L. Hanzo, P.J. Cherriman, J. Streit, IEEE Series onDigital and Mobile Communication, 2001.
EE610	ANALOG/DIGITAL VLSI CIRCUITS	3-0-0--4	Analog MOS circuits, opamps, frequency and transient responses, stability and compensation. Analog switches, sample and hold circuits, switched capacitor circuits. MOS inverters and gate circuits, interfacing, transmission gates. MOS memory circuits. Digital building blocks multiplexers, decoders, shift registers, etc. Gate array, standard cell, and PLA based designs. Digital to Analog and Analog to Digital converters.
EE610A	ANALOG/DIGITAL VLSI CIRCUITS	3-0-0-0-9	Analog MOS circuits, opamps, frequency and transient responses, stability and compensation. Analog switches, sample and hold circuits, switched capacitor circuits. MOS inverters and gate circuits, interfacing, transmission gates. MOSmemory circuits. Digital building blocks multiplexers, decoders, shift registers, etc. Gate array, standard cell, and PLA based designs. Digital to Analog and Analog to Digital converters.
EE611	ORGANIC ELECTRONICS	3-0-0--4	Lectures: General Overview of Organic Semiconductors and Electronics; Introduction to some of the basics of Molecular Quantum Mechanics; Optical and Electrical Properties of Organic Semiconductor Material; Organic Thin Film Transistor (OTFT) physics and processing; Organic Light Emitting Diode (OLED) physics and processing; OLED passive and active matrix displays, OTFT circuits; Organic Solar Cell physics and processing; Research opportunities in organic electronics and the associated technologies.Labs: Fabrication of an organic device and its characterisation The purpose of this course is (i) to give the student an introduction to the world of organic electronics and (ii) to help students appreciate practical organic electronic devices and th associated technologies. **Course Reference**: 1. This course was started for the first time by Prof. Baquer Mazhari who offered it as EE698A I Spring 2005 and 2006. It was offered as EE698W by Dr. S. Sundar Kumar Iyer in Spring 2007 Summer courses have also been offered on this topic in the summers of 2005, 2006 and 2007 the faculty members involved in Samtel Centre for Display Technology, IIT Kanpur
EE611A	ORGANIC ELECTRONICS	3-0-3-0-12	Lectures: General Overview of Organic Semiconductors and Electronics; Introduction to some of the basics of Molecular Quantum Mechanics; Optical and Electrical Properties of Organic Semiconductor Material; Organic Thin Film Transistor (OTFT) physics and processing; Organic Light Emitting Diode (OLED) physics and processing; OLED passive and active matrix displays, OTFT circuits; Organic Solar Cell physics and processing; Research opportunities in organic electronics and the associated technologies.Labs: Fabrication of an organic device and its characterisation The purpose of this course is (i) to give the student an introduction to the world of organi electronics and (ii) to help students appreciate practical organic electronic devices and th associated technologies. **Course Reference**: 1. This course was started for the first time

			by Prof. Baquer Mazhari who offered it as EE698A I Spring 2005 and 2006. It was offered as EE698W by Dr. S. Sundar Kumar Iyer in Spring 2007 Summer courses have also been offered on this topic in the summers of 2005, 2006 and 2007 the faculty members involved in Samtel Centre for Display Technology, IIT Kanpur
EE612	FIBER OPTIC SYSTEMS I	3-0-0--4	Review of semiconductor physics radiative recombination. LEDs, optical cavity, DH and other lasers. PIN and APD detectors, detector noise. Optical fibers ray and mode theories, multimode and single mode fibers, attenuation dispersion. Gaussian beams. Power coupling, splices and connectors.
EE612A	FIBER OPTIC SYSTEMS I	3-0-0-0-9	Review of semiconductor physics radiative recombination. LEDs, optical cavity, DH and other lasers. PIN and APD detectors, detector noise. Optical fibers ray and mode theories, multimode and singlemode fibers, attenuation, dispersion. Gaussian beams. Power coupling, splices and connectors.
EE614	SOLID STATE DEVICES I	3-0-0--4	Basic semiconductor physics. Diodes (PN junction, Schottky, contact), Junction Transistors (BJT, HBT), Field Effect Transistors (JEFT, MESFET, MOSFET, HEMT). Other, semiconductor devices.
EE614A	SOLID STATE DEVICES I	3-0-0-0-9	Basic semiconductor physics. Diodes (PN junction, Schottky, contact), JunctionTransistors (BJT, HBT), Field Effect Transistors (JEFT, MESFET, MOSFET, HEMT). Other, semiconductor devices.
EE615	HIGH FREQUENCY SEMICONDUCTOR DEVICES AND CIRCUITS	3-0-0--4	Review of Semiconductor properties Crystal structure of semiconductors, bandtheory, occupation statistics, electrical properties, optical properties, recombination kinetics, avalanche process in semiconductors, photon statistics; MESFETs;Transport in low dimensional structures: HEMTs: Hetrojunction BJTs; Design ofhigh frequency amplifiers and oscillators, Resonant tunneling structures, RTD oscillators; Intervalley scattering, Gunn diodes, IMPATT diodes; TRAPATTs; Mixerdiodes; Step recovery diodes; Introduction to epitaxial growth for these structures; elements of device fabrication.
EE616	SEMICONDUCTOR DEVICE MODELLING	3-0-0--4	Models for metal semiconductor contacts and heterojunctions. MOSFET quantum theory of 2DEG, gradual channel approximation, charge control models, BSIM model, secondorder effects. MESFET Shockley, velocity saturation anduniversal models. HEFT Basic and universal models. SPICE and small signal models.
EE616A	SEMICONDUCTOR DEVICE MODELLING	3-0-0-0-9	Models for metal semiconductor contacts and heterojunctions. MOSFET quantum theory of 2DEG, gradual channel approximation, charge control models, BSIM model, second order effects. MESFET Shockley, velocity saturation and universal models. HEFT Basic and universal models. SPICE and small signal models.
EE618	INTEGRATED CIRCUIT FABRICATION TECHNOLOGY	3-0-0--4	IC components their characterization and design. Anaysis and design of basic logic circuits. Linear ICs. Large Scale Integration. Computer simulation of ICs and layout design. High Voltage ICs. GaAs MESFET and GaAs ICs. Failure, reliability and yield of ICs. Fault modeling and testing.

EE618A	INTEGRATED CIRCUIT FABRICATION TECHNOLOGY	3-0-0-0-9	IC components their characterization and design. Anaysis and design of basic logic circuits. Linear ICs. Large Scale Integration. Computer simulation of ICsand layout design. High Voltage ICs. GaAs MESFET and GaAs ICs. Failure, reliability and yield of ICs. Fault modeling and testing.
EE619	VLSI SYSTEM DESIGN	3-0-0-0-4	Emphasis on the synthesis-based approach to VLSI Design. Relevant issues related to physical design automation such as placement, floor planning, routing and compaction are covered. Combinational & sequential logic synthesis issues and algotithms are discussed. Detailed coverage of HDLs and high-level synthesis algorithms and issues.
EE619A	VLSI SYSTEM DESIGN	3-0-0-0-9	Emphasis on the synthesis-based approach to VLSI Design. Relevant issues related to physical design automation such as placement, floor planning, routing and compaction are covered. Combinational & sequential logic synthesis issues and algotithms are discussed. Detailed coverage of HDLs and high -level synthesis algorithms and issues.
EE621	REPRESENTATION AND ANALYSIS OF RANDOM SIGNALS	3-0-0--4	Review of probability, random variables, random processes; representation of narrow band signals. Transmission of signals through LTI systems; Estimation and detection with random sequences; BAYES, MMSE, MAP, ML schemes. KLand sampling theorem representations, matched filter, ambiguity functions, Markov sequences, linear stochastic dynamical systems.
EE621A	REPRESENTATION AND ANALYSIS OF RANDOM SIGNALS	3-0-0-0-9	Review of probability, random variables, random processes; representation of narrow band signals. Transmission of signals through LTI systems; Estimation and detection with random sequences; BAYES, MMSE, MAP, ML schemes. KLand sampling theorem representations, matched filter, ambiguity functions, Markov sequences, linear stochastic dynamical systems.
EE622	COMMUNICATION THEORY	3-0-0--4	Rate Distortion Theory, Channel Coding Theorems, Digital Modulation Schemes, Trellis Coded Modulation, Digital Transmission over Bandlimited Channels, Fading Multipath Channels, Synchronization. Analog Modulation Schemes, Optimum/Suboptimum Receivers; Diversity Combining; Cellular Mobile Communciation; Equalization.
EE622A	COMMUNICATION THEORY	3-0-0-0-9	Rate Distortion Theory, Channel Coding Theorems, Digital Modulation Schemes, Trellis Coded Modulation, Digital Transmission over Bandlimited Channels, Fading Multipath Channels, Synchronization. Analog Modulation Schemes, Optimum/Suboptimum Receivers; Diversity Combining; Cellular Mobile Communciation; Equalization.
EE623	DETECTION & ESTIMATION THEORY	3-0-0--4	Classical Detection and Estimation Theory, Signal Representation, Detection ofsignals in Gaussian noise, Waveform estimation, Linear estimation problems, Wiener filtering, Kalman filtering.
EE623A	DETECTION & ESTIMATION THEORY	3-0-0-0-9	Classical Detection and Estimation Theory, Signal Representation, Detection of signals in Gaussian noise, Waveform estimation, Linear estimation problems, Wiener filtering, Kalman filtering.
EE624	INFORMATION AND	3-0-0--4	Entropy and mutual information, rate distortion function, source

	CODING THEORY		coding, variable length coding, discrete memoryless channels, capacity cost functions, channel coding, linear block codes, cyclic codes. Convolutional codes, sequential and probabilistic decoding, majority logic decoding, burst error correcting codes.
EE624A	INFORMATION AND CODING THEORY	3-0-0-0-9	Entropy and mutual information, rate distortion function, source coding, variable length coding, discrete memoryless channels, capacity cost functions, channel coding, linear block codes, cyclic codes. Convolutional codes, sequential and probabilistic decoding, majority logic decoding, burst error correcting codes.
EE626	TOPICS IN STOCHASTIC PROCESSES	3-0-0--4	Martingale convergence theorem, stopping times, sequential analysis. Ergodic Theory: Measure preserving transformations, stationary processes, mixing conditions, ergodic theorem, Shannon Millan Breiman theorem. Markov chains asymptotic stationarity, indecomposability, ergodicity. Continuous time processes: Separability, continuity, measurability, stochastic integral.
EE626A	TOPICS IN STOCHASTIC PROCESSES	3-0-0-0-9	Martingale convergence theorem, stopping times, sequential analysis. Ergodic Theory: Measure preserving transformations, stationary processes, mixing conditions, ergodic theorem, Shannon Millan Breiman theorem. Markov chains asymptotic stationarity, indecomposability, ergodicity. Continuous time processes: Separability, continuity, measurability, stochastic integral.
EE627	SPEECH SIGNAL PROCESSING	3-0-0-0-4	Spectral and nonspectral analysis techniques; Model based coding techniques; Noise reduction and echo cancellation; Synthetic and coded speech quality assessment; Selection of recognition unit; Model based recognition; Language modelling; Speaker Identification; Text analysis and text to speech synthesis.
EE627A	SPEECH SIGNAL PROCESSING	3-0-0-0-9	Spectral and nonspectral analysis techniques; Model based coding techniques; Noise reduction and echo cancellation; Synthetic and coded speech quality assessment; Selection of recognition unit; Model based recognition; Language modelling; Speaker Identification; Text analysis and text to speech synthesis.
EE628	TOPICS IN CRYPTOGRAPHY AND CODING	3-0-0--4	Cryptography and error control coding in communication and computing systems. Stream and block ciphers; DES; publickey cryptosystems; key management, authentication and digital signatures. Codes as ideals in finite commutative rings and group algebras. Joint coding and cryptography.
EE629	DIGITAL SWITCHING	3-0-0--4	Network Architecture; time division multiplexing; digital switching; space & time division switching, cross point and memory requirements; blocking probabilities. traffic Analysis, models for circuit and packet switched systems, performance comparison; ISDN.
EE629A	DIGITAL SWITCHING	3-0-0-0-9	Network Architecture; time division multiplexing; digital switching; space & time division switching, cross point and memory requirements; blocking probabilities. traffic Analysis, models for circuit and packet switched systems, performance comparison; ISDN.
EE630	SIMULATON OF MODERN POWER	3-0-3-0-5	Modern power systems operation and control, Power system deregulation; static and dynamic modeling; Load flow and

	SYSTEMS		stability studies; Electromagnetic phenomenon; Insulation and partial discharge.
EE630A	SIMULATON OF MODERN POWER SYSTEMS	3-0-3-0-12	Modern power systems operation and control, Power system deregulation; static and dynamic modeling; Load flow and stability studies; Electromagnetic phenomenon; Insulation and partial discharge.
EE631	ADVANCED POWER SYSTEM STABILITY	3-0-0--4	Detailed machine modeling, Modeling of turbine generator and associated systems, excitation systems and PSS, Transient stability and small signal stabilityfor large systems, SSR and system modeling for SSR studies, Voltage stability: PV and QV curves, static analysis, sensitivity and continuation method; Dynamic analysis, local and global bifurcations, Control area, Margin prediction, Stability of ACDC systems.
EE631A	ADVANCED POWER SYSTEM STABILITY	3-0-0-0-9	Detailed machine modeling, Modeling of turbine generator and associated systems, excitation systems and PSS, Transient stability and small signal stability for large systems, SSR and system modeling for SSR studies, Voltage stability: PV and QV curves, static analysis, sensitivity and continuation method; Dynamic analysis, local and global bifurcations, Control area, Margin prediction, Stability of ACDC systems.
EE632	ECONOMIC OPERATION & CONTROL OF POWER SYSTEMS	3-0-0--4	Economic load dispatch, loss formula, introduction to mathematical programming, hydrothermal scheduling systems, power system security, optimal real and reactive power dispatch, state estimation, load frequency control, energy control center.
EE632A	ECONOMIC OPERATION & CONTROL OF POWER SYSTEMS	3-0-0-0-9	Economic load dispatch, loss formula, introduction to mathematical programming, hydrothermal scheduling systems, power system security, optimal real and reactive power dispatch, state estimation, load frequency control, energy control center.
EE633	ELECTRIC POWER SYSTEM OPERATION AND MGMT. UNDER RESTRUCTURED ENVIRONMENT	3-0-0--4	Fundamentals of deregulation: Privatization and deregulation, Motivations for Restructuring the Power industry; Restructuring models and Trading Arrangements: Components of restructured systems, Independent System Operator (ISO): Functions and responsibilities, Trading arrangements (Pool, bilateral & multilateral),Open Access Transmission Systems; Different models of deregulation: U K Model, California model, Australian and New Zealand models, Deregulation in Asia including India, Bidding strategies, Forward and Future market; Operation andcontrol: Old vs New, Available Transfer Capability, Congestion management, Ancillary services; Wheeling charges and pricing: Wheeling methodologies, pricing strategies.
EE633A	ELECTRIC POWER SYSTEM OPERATION AND MGMT. UNDER RESTRUCTURED ENVIRONMENT	3-0-0-0-9	Fundamentals of deregulation: Privatization and deregulation, Motivations for Restructuring the Power industry; Restructuring models and Trading Arrangements: Components of restructured systems, Independent System Operator (ISO):Functions and responsibilities, Trading arrangements (Pool, bilateral & multilateral), Open Access Transmission Systems; Different models of deregulation: U K Model,California model, Australian and New Zealand models, Deregulation in Asia including India, Bidding strategies, Forward and Future market; Operation and control: Old vs New, Available Transfer Capability, Congestion management, Ancillary services; Wheeling charges and pricing: Wheeling methodologies, pricing strategies.

EE634	ELECTRICAL INSULATION IN POWER APPARATUS AND SYSTEMS	3-0-0--4	Properties of dielectrics and breakdown mechanisms; composites and novelmaterials; insulators for outdoor applications. Issues in design of insulators and insulator systems. Overvoltages and insulation coordination in transmission networks. Generation and measurement of testing Voltages DC, AC, impulse andpulsed. Testing and Evaluation: Procedures and standards, ageing studies. On line and off-line condition monitoring of substation equipment. Advances in measurement and diagnostic technologies: partial discharge monitoring, space charge charge measurements, dielectric spectroscopy etc. Lab demonstrations.
EE634A	ELECTRICAL INSULATION IN POWER APPARATUS AND SYSTEMS	3-0-0-0-9	Properties of dielectrics and breakdown mechanisms; composites and novel materials; insulators for outdoor applications. Issues in design of insulators and insulator systems. Overvoltages and insulation coordination in transmission networks. Generation and measurement of testing Voltages DC, AC, impulse andpulsed. Testing and Evaluation: Procedures and standards, ageing studies. On line and off-line condition monitoring of substation equipment. Advances in measurement and diagnostic technologies: partial discharge monitoring, space charge charge measurements, dielectric spectroscopy, etc. Lab demonstrations.
EE635	HVDC TRANSMISSION & FLEXIBLE A C TRANSMISSION SYSTEMS	3-0-0--4	General aspects of DC transmission, converter circuits and their analysis, DClink controls, faults and abnormal operation and protection; Mechanism of activeand reactive power flow contro; Basic FACTS controllers: SVC, STATCOM, TCSC, TCPAR, UPFC; Modeling of FACTS Controllers; System static performance improvement with FACTS controllers; System dynamic performance improvement with FACTS controllers.
EE635A	HVDC TRANSMISSION & FLEXIBLE A C TRANSMISSION SYSTEMS	3-0-0-0-9	General aspects of DC transmission, converter circuits and their analysis, DClink controls, faults and abnormal operation and protection; Mechanism of activeand reactive power flow contro; Basic FACTS controllers: SVC, STATCOM, TCSC, TCPAR, UPFC; Modeling of FACTS Controllers; System static performance improvement with FACTS controllers; System dynamic performance improvement with FACTS controllers.
EE636A	ADVANCED PROTECTIVE RELAYING	3-0-0-0-9	Advanced protective relaying, basic protection schemes, relay terminology, relays as comparators, static relays, application of solid-state devices, differential relaying systems, distance relaying schemes, protection of multiterminal lines, new types of relaying criteria, special problems, digital protection.
EE639	NONLINEAR FIBER OPTICS	3-0-0-0-4	1. Introduction: Linear vs Nonlinear effects in optical fiber, Important nonlinear effects and their impact on optical communication, applications of optical nonlinearities to signal processing; 2. Electromagnetic wave propagation in fibers: Wave equation for linear media, phase and group velocities, reflection and transmission of waves, structure of an optical fiber, wave equation in cylindrical coordinates, fiber modes, characteristics of LPm mode; 3. Dispersion in optical fibers: Chromatic dispersion in single mode fibers, effect on pulse propagation, dispersion management and compensation, polarization mode dispersion first and second order models, effect on communication system , mitigation of PMD; 4.

			FourWave mixing (FWM): Mathematical description, phase matching, fiber parametric am plifiers using FWM, squeezed state and entangled photon pair generation using FWM , impact on communication system; 5. Nonlinear phase modulation: SelfPhase modulation, impact on communication system, modulation instability, Cross Phase modulation, impact on communication system; 6. Nonlinear Schrodinger equation (NLSE): Nonlinear polarization, nonlinear refractive in dex, derivation of NLSE, effect of dispersion only, effect of nonlinearity only, soliton solutions,numerical .solution of the NLSE.
EE640	COMPUTATIONAL ELECTROMAGNETICS	3-0-0-0-4	Review of complex variables, conformal mappings, matrix calculus; Sturm Liouville equation; Eigenvalue problem; Guiding structures; Scattering media; Greens function approach; Variational formulation, FEM, Generalised scattering matrix and planar circuit approach.
EE640A	COMPUTATIONAL ELECTROMAGNETICS	3-0-0-0-9	Review of complex variables, conformal mappings, matrix calculus; SturmLiouville equation; Eigenvalue problem; Guiding structures; Scattering media; Greens function approach; Variational formulation, FEM, Generalised scattering matrix and planar circuit approach.
EE641	ADVANCED ENGINEERING ELECTROMAGNETICS	3-0-0--4	Transmission line theory; Greens function and integral transform techniques; Wave propagation and polarization parameters; reflection and transmission across an interface; waveguides, cavity resonators, scattering by cylinders, wedges, spheres etc. Geometric theory of diffraction.
EE641A	ADVANCED ENGINEERING ELECTROMAGNETICS	3-0-0-0-9	Transmission line theory; Greens function and integral transform techniques; Wave propagation and polarization parameters; reflection and transmission across an interface; waveguides, cavity resonators, scattering by cylinders, wedges, spheres etc. Geometric theory of diffraction.
EE642	ANTENNAS ANALYSIS & SYNTHESIS	3-0-0--4	Vector potential; antenna theorems and definitions; dipole, loop, slot radiators; aperture antennas; array theorems; pattern synthesis; self and mutual impedances; scanning antennas; signal processing antennas, travelling wave antennas; antenna measurements.
EE642A	ANTENNAS ANALYSIS & SYNTHESIS	3-0-0-0-9	Vector potential; antenna theorems and definitions; dipole, loop, slot radiators; aperture antennas; array theorems; pattern synthesis; self and mutual impedances; scanning antennas; signal processing antennas, travelling wave antennas; antenna measurements.
EE643	SMART ANTENNAS FOR MOBILE COMMUNICATION	3-0-0--4	Statistical signal processing concepts, Basics of mobile wireless communications. Radio Frequency signal modeling and channel characterization. Smart antennas and generalized array signal processing. Source localization problem. Joint angle and delay estimation. Smart antenna array configurations. Mobile communication systems with smart antennas.
EE643A	SMART ANTENNAS FOR MOBILE COMMUNICATION	3-0-0-0-9	Statistical signal processing concepts, Basics of mobile wireless communications. Radio Frequency signal modeling and channel characterization. Smart antennas and generalized array signal processing. Source localization problem. Joint angleand delay estimation. Smart antenna array configurations. Mobile

			communication systems with smart antennas.
EE645	MONOLITHIC MICROWAVE ICS	3-0-0--4	Scattering parameters of nports, Conductor and dielectric losses in planar transmission lines, coupled lines, multiconductor lines, discontinuities, GaAsMESFET fabrication devices, High electron mobility transistor, Heterojunction bipolar transistor fabrication and modeling, NMIC technology and design.
EE645A	MONOLITHIC MICROWAVE ICS	3-0-0-0-9	Scattering parameters of nports, Conductor and dielectric losses in planar transmission lines, coupled lines, multiconductor lines, discontinuities, GaAsMESFET fabrication devices, High electron mobility transistor, Hetero junction bipolar transistor fabrication and modeling, NMIC technology and design.
EE646	PHOTONIC NETWORKS & SWITCHING	3-0-0--4	Optical communications: Introduction to basic optical communications and devices. Optical multiplexing techniques Wavelength division multiplexing, Optical frequency division multiplexing, time division multiplexing, code division multiplexing. Optical Networks: Conventional optical networks, SONET / SDH, FDDI, IEEE 802.3, DQDB, FCS, HIPPI etc. Multiple access optical networks, T opologies, Single channel networks, Multichannel networks, FTFR, FTTR, TTFRand TTTR, Single hop networks, Multihop networks, Multiaccess protocols forWDM networks, Switched optical networks. Optical amplification in alloptical networks. Alloptical subscriber access networks. Design issues. Optical switching: Motivation, Spatial light modulator, Relational and nonrelational switching devices, Fundamental limits on optical switching elements, Switching architectures, Freespace optical switching. Wavelength routed networks and other special topics. Soliton based networks, Optical networks management issues.
EE646A	PHOTONIC NETWORKS & SWITCHING	3-0-0-0-9	Optical communications: Introduction to basic optical communications anddevices. Optical multiplexing techniques Wavelength division multiplexing, Optical frequency division multiplexing, time division multiplexing, code divisionmultiplexing. Optical Networks: Conventional optical networks, SONET / SDH, FDDI, IEEE 802.3, DQDB, FCS, HIPPI etc. Multiple access optical networks, T opologies, Single channel networks, Multichannel networks, FTFR, FTTR, TTFRand TTTR, Single hop networks, Multihop networks, Multiaccess protocols for WDM networks, Switched optical networks. Optical amplification in all optical networks. Alloptical subscriber access networks. Design issues. Optical switching: Motivation, Spatial light modulator, Relational and nonrelational switching devices, Fundamental limits on optical switching elements, Switching architectures, Freespace optical switching. Wavelength routed networks and other specialtopics. Soliton based networks, Optical networks management issues.
EE647	MICROWAVE MEASUREMENTS AND DESIGN	2-0-3-0-4	Experiments in basic microwave measurements; passive and active circuit characterization using network analyser, spectrum analyser and noise figure meter; PC based automated microwave measurements; integration of measurement and design of microwave circuits.
EE647A	MICROWAVE MEASUREMENTS	2-0-3-0-9	Experiments in basic microwave measurements; passive and active circuit characterization using network analyser, spectrum

	AND DESIGN		analyser and noise figure meter; PC based automated microwave measurements; integration of measurement and design of microwave circuits.
EE648	MICROWAVE CIRCUITS	3-0-0--4	Transmission lines for microwave circuits; waveguides, stripline, microstrip, slotline; microwave circuit design principles; passive circuits; impedance transformers, filters, hybrids, isolators etc., active circuits using semiconductor devices andtubes, detection and measurement of microwave signals.
EE648A	MICROWAVE CIRCUITS	3-0-0-0-9	Transmission lines for microwave circuits; waveguides, stripline, microstrip, slotline; microwave circuit design principles; passive circuits; impedance transformers, filters, hybrids, isolators etc., active circuits using semiconductor devices and tubes, detection and measurement of microwave signals.
EE649	THE FINITE ELEMENT METHOD FOR ELECTRIC AND MAGNETIC FIELDS	3-0-0-0-4	Introduction: Review of Electromagnetic Theory. Introduction to the Finite Element Method using electrostatic fields: Galerkin s method of weighted residuals, Minimum energy principle, Calculation of capacitance, electric field, electric forces from the potential solutions. Finite Element Concepts: Pre-processing, shape functions, isoparmetric elements, meshing, solvers, post processing. finite Element Modeling: Conductive media, steady currents; Magnetostatic fields, permanent Magnets, scalar and vector potentials; Electromagnetic fields. eddy current problems, modeling of moving parts; modeling ofelectrical circuits.
EE649A	THE FINITE ELEMENT METHOD FOR ELECTRIC AND MAGNETIC FIELDS	3-0-3-0-12	Introduction: Review of Electromagnetic Theory. Introduction to the Finite Element Method using electrostatic fields: Galerkin’s method of weighted residuals, Minimum energy principle, Calculation of capacitance, electric field, electric forces from the potential solutions. Finite Element Concepts: Pre-processing, shape functions, isoparmetric elements, meshing, solvers, post processing. finite Element Modeling: Conductive media, steady currents; Magnetostatic fields, permanent Magnets, scalar and vector potentials; Electromagnetic fields. eddy current problems, modeling of moving parts; modeling of electrical circuits.
EE650	BASICS OF MODERN CONTROL SYSTEMS	3-0-0--4	Vector spaces, Linear systems, similarity transformations, Canonical forms, Controllability, Observability, Realisability etc. Minimal realization, Digital systems, Nonlinear systems, Phaseplane analysis, Poincare theorems, Lyapunov theorem, Circle and Popov criterion; Robust control, Linear Quadratic Regulator (LQR), Linear Quadratic Gaussian (LQG) control, Loop Transfer Recovery (LTR), Hinfinitycontrol.
EE650A	BASICS OF MODERN CONTROL SYSTEMS	3-0-0-0-9	Vector spaces, Linear systems, similarity transformations, Canonical forms, Controllability, Observability, Realisability etc. Minimal realization, Digital systems, Nonlinear systems, Phaseplane analysis, Poincare theorems, Lyapunov theorem, Circle and Popov criterion; Robust control, Linear Quadratic Regulator (LQR), Linear Quadratic Gaussian (LQG) control, Loop Transfer Recovery (LTR), Hinfinity control.
EE653	DIGITAL CONTROL	3-0-0-0-4	Discretetime signals and systems, Ztransform, pulse transfer functions. Compensator design by root locus, error coefficients and frequency response. Statespace models of discrete time systems, controllability, observability, stability, state estimation, Kalman filtering. Linear regulation. Parameter estimation.

EE653A	DIGITAL CONTROL	3-0-0-0-9	Discrete time signals and systems, Ztransform, pulse transfer functions. Compensator design by root locus, error coefficients and frequency response. Statespace models of discrete time systems, controllability, observability, stability, state estimation, Kalman filtering. Linear regulation. Parameter estimation.
EE654	ROBUST CONTROL SYSTEMS	3-0-0--4	Linear Quadratic Regulators: return ratio & difference, sensitivity function. Kalmans optimality condition. Gain/phase margins, robustness to time delayand nonlinearity. Characterization of sensitivity. Kharitonov theorem robustness. Singular values properties, application in stability, robustness and sensitivity. Robustness of discrete time LQR systems.
EE654A	ROBUST CONTROL SYSTEMS	3-0-0-0-9	Linear Quadratic Regulators: return ratio & difference, sensitivity function. Kalmans optimality condition. Gain/phase margins, robustness to time delay and nonlinearity. Characterization of sensitivity. Kharitonov theorem robustness. Singular values properties, application in stability, robustness and sensitivity. Robustness of discrete time LQR systems.
EE658	FUZZY SET, LOGIC & SYSTEMS & APPLICATIONS	3-0-0--4	Introduction, Uncertainity, Imprecision and Vagueness, Fuzzy systems, Brief history of Fuzzy logic, Foundation of Fuzzy Theory, Fuzzy Sets and Systems, Fuzzy Systems in Commercial Products, Research Fields in Fuzzy Theory, Classical sets and Fuzzy sets, Classical Relations, Fuzzy relations, Membership Functions,Fuzzy to crisp conversions, Fuzzy arithmetic, Numbers, Vectors and the extension principle, Classical logic and Fuzzy logic, Mathematical back ground of Fuzzy Systems, Classical (Crisp) vs, Fuzzy sets, Representation of Fuzzy sets, Typesof Membership Functions, Basic Concepts (support, singleton, height, acut projections), Fuzzy set operations, Sand T Norms, Properties of Fuzzy sets,Sets as Points in Hypercube, Cartesian Product, Crisp and Fuzzy Relations, Examples, Liguistic variables and hedges, Membership function design. Basic Principles of Inference in Fuzzy Logic, Fuzzy IFTHEN Rules, Canonical Form, Fuzzy Systems and Algorithms, Approximate Reasoning, Forms of Fuzzy Implication, Fuzzy Inference Engines, Graphical Techniques of Inference, Fuzzyifications/DeFuzzification, Fuzzy System Design and its Elements, Design options. Fuzzy Events, Fuzzy Measures, Possibility Distributions as Fuzzy Sets, Possibility vs, Probability Fuzzy Systems as Universal Approximators, Additive Fuzzy Systems (standard additive model).
EE658A	FUZZY SET, LOGIC & SYSTEMS & APPLICATIONS	3-0-0-0-9	Introduction, Uncertainity, Imprecision and Vagueness, Fuzzy systems, Brief history of Fuzzy logic, Foundation of Fuzzy Theory, Fuzzy Sets and Systems,Fuzzy Systems in Commercial Products, Research Fields in Fuzzy Theory, Classical sets and Fuzzy sets, Classical Relations, Fuzzy relations, Membership Functions,Fuzzy to crisp conversions, Fuzzy arithmetic, Numbers, Vectors and the extension principle, Classical logic and Fuzzy logic, Mathematical back ground of Fuzzy Systems, Classical (Crisp) vs, Fuzzy sets, Representation of Fuzzy sets, Typesof Membership Functions, Basic Concepts (support, singleton, height, acut projections), Fuzzy set operations, Sand T Norms, Properties of Fuzzy sets,Sets as Points in Hypercube,

			Cartesian Product, Crisp and Fuzzy Relations,Examples, Liguistic variables and hedges, Membership function design. Basic Principles of Inference in Fuzzy Logic, Fuzzy IFTHEN Rules, Canonical Form, Fuzzy Systems and Algorithms, Approximate Reasoning, Forms of Fuzzy Implication, Fuzzy Inference Engines, Graphical Techniques of Inference, Fuzzyifications/DeFuzzification, Fuzzy System Design and its Elements, Design options. FuzzyEvents, Fuzzy Measures, Possibility Distributions as Fuzzy Sets, Possibility vs, Probability, Fuzzy Systems as Universal Approximators, Additive Fuzzy Systems (standard additive model).
EE659	COMPUTATIONAL ASPECTS OF TOMOGRAPHIC IMAGING : MODELS TO INVERSIONS	3-0-0-0-4	1. Motivations and overview of of tomography, limited data settings, approximate tomography, multimodal tomography; 2. Typical Models : Maxwells equations, Helmholtz equation, eikonal equation,radiative transfer equation and its diffusion approximation; 3. Brief review of numerical solutions to the above models: finite element schemes and the method of moments (boundary element method); 4. Linear tomography: Straight path tomography, Born and Rytov approximations in diffraction tomography, algebraic reconstruction techniques; 5. Regularized linear and nonlinear least squares solutions; 6. Frechet derivative calculations, method of adjoints; 7. Approximate tomography: Shape based tomography and topological derivatives; 8. Introduction to stochastic reconstruction schemes, maximum likelihood and Bayesian methods, posterior sampling; 9. Applications: Diffuse optical tomography, electrical impedance tomography,refraction tomography, electromagnetic wave tomography, elastography,multimodal tomography.
EE659A	COMPUTATIONAL ASPECTS OF TOMOGRAPHIC IMAGING : MODELS TO INVERSIONS	3-0-0-0-9	1. Motivations and overview of of tomography, limited data settings, approximate tomography, multimodal tomography; 2. Typical Models : Maxwells equations, Helmholtz equation, eikonal equation,radiative transfer equation and its diffusion approximation; 3. Brief review of numerical solutions to the above models: finite element schemesand the method of moments (boundary element method); 4. Linear tomography: Straight path tomography, Born and Rytov approximations in diffraction tomography, algebraic reconstruction techniques; 5. Regularized linear and nonlinear least squares solutions; 6. Frechet derivative calculations , method of adjoints; 7. Approximate tomography: Shape based tomography and topological derivatives; 8. Introduction to stochastic reconstruction schemes, maximum likelihood and Bayesian methods, posterior sampling; 9. Applications: Diffuse optical tomography, electrical impedance tomography,refraction tomography, electromagnetic wave tomography, elastography, multimodal tomography.
EE660	BASICS OF POWER ELECTRONIC CONVERTERS	3-0-3--5	Power semiconductor devices, BJT, MOSFET, IGBT, GTO and MCT: ACDC Converters; Forced communication; synchronous link converters, DCAC converters, buck, boost, buckboost, cuk, flyback configuration, resonant converters, PWM inverters; active filters.
EE660A	BASICS OF POWER	3-0-3-0-12	Power semiconductor devices, BJT, MOSFET, IGBT, GTO and

	ELECTRONIC CONVERTERS		MCT: ACDC Converters; Forced communication; synchronous link converters, DCAC converters, buck, boost, buckboost, cuk, flyback configuration, resonant converters, PWM inverters; active filters.
EE661	POWER ELECTRONICS APPLICATIONS IN POWER SYSTEMS	3-0-0--4	Basics of flexible AC transmission systems, Controlled rectifier and energy storage plants, Tap-changers and phase shifters, Thyristor controlled VAR compensation and series compensation, Modern (synchronous link converter) VAR compensators, Unified power flow controller (UPFC) and Inter line power flow controller, Power quality conditioners, Power electronics in power generation.
EE661A	POWER ELECTRONICS APPLICATIONS IN POWER SYSTEMS	3-0-0-0-9	Basics of flexible AC transmission systems, Controlled rectifier and energy storage plants, Tap-changers and phase shifters, Thyristor controlled VAR compensation and series compensation, Modern (synchronous link converter) VAR compensators, Unified power flow controller (UPFC) and Interline power flow controller, Power quality conditioners, Power electronics in power generation.
EE662	CONTROL TECHNIQUES IN POWER ELECTRONICS	3-0-0--4	State space modeling and simulation of linear systems, Discrete time models, conventional controllers using small signal models, Fuzzy control, Variable structure control, Hysteresis controllers, Output and state feedback switching controllers.
EE662A	CONTROL TECHNIQUES IN POWER ELECTRONICS	3-0-0-0-9	State space modeling and simulation of linear systems, Discrete time models, conventional controllers using small signal models, Fuzzy control, Variable structure control, Hysteresis controllers, Output and state feedback switching controllers.
EE664	FUNDAMENTALS OF ELECTRIC DRIVES	3-0-0--4	Motor load dynamics, starting, braking & speed control of dc and ac motors. DC drives: converter and chopper control. AC Drives: Operation of inductionand synchronous motors from voltage and current inverters, slip power recovery, pump drives using ac line controller and self-controlled synchronous motor drives.
EE664A	FUNDAMENTALS OF ELECTRIC DRIVES	3-0-0-0-9	Motor load dynamics, starting, braking & speed control of dc and ac motors. DC drives: converter and chopper control. AC Drives: Operation of induction and synchronous motors from voltage and current inverters, slip power recovery, pump drives using ac line controller and self-controlled synchronous motor drives.
EE665	ADVANCED ELECTRIC DRIVES	3-0-0--4	Closed loop control of solidstate DC drives, Scalar and vector control of induction motor, Direct torque and flux control of induction motor, Self controlled synchronous motor drive, Vector control of synchronous motor, Switched reluctance motor drive, Brushless DC motor drive, Permanent magnet drives, Industrial drives.
EE665A	ADVANCED ELECTRIC DRIVES	3-0-0-0-9	Closed loop control of solidstate DC drives, Scalar and vector control of induction motor, Direct torque and flux control of induction motor, Self controlled synchronous motor drive, Vector control of synchronous motor, Switched reluctance motor drive, Brushless DC motor drive, Permanent magnet drives, Industrial drives.
EE666	SPECIAL TOPICS IN POWER ELECTRONICS	3-0-0-0-4	PWM inverters, Multilevel inverters, Neutral point -controlled inverters, Softswitching converters: DC-DC resonant link inverters, Hybrid resonant link inverters, Quasi resonant link converters, Switched mode rectifiers, Synchronous link

			converters.
EE666A	SPECIAL TOPICS IN POWER ELECTRONICS	3-0-0-0-9	PWM inverters, Multilevel inverters, Neutral point -controlled inverters, Softswitching converters: DCDC resonant link inverters, Hybrid resonant link inverters, Quasi resonant link converters, Switched mode rectifiers, Synchronous link converters.
EE667	INFORMATION THEORY	3-0-0-0-4	Introduction: Entropy, Relative Entropy, Mutual Information Inequalities, Entropy rate. Ansymptotic Equipartition Property (AEP): Consequences of the AEP, Typical Sequences, Shannon McMillan Breiman Theorem. Data Compression: Block to variable lenght codes, Shannon Fano code, Huffman code, variable to fixed lenght coding Tunstal code, variable to variable length codes/ arithmetic code. Channel capacity: Discrete Memoryless Channel, Joint Typicality, Channel Coding Theorem and its converse, Feedback capacity, Source Channel Separation Theorem. Differential Entropy: Difinition, Properties. Gaussian Channel: Definition, Parallel Gaussian Channels, Channels with Colored Gaussian Noise, Gaussian Channels with Feedback. Rate Distortion Theory: Rate Distortion Function, Rate Distortion theorem and its converse, Blahut Arimoto Algorithm. Universal Source Coding: Universal codes, LempelZiv codes; LZ 78, LZW, Slinding Window Lempel Ziv algorithm (LZ77). Network Information Theory: Gaussian MultiUser Channels, Multiple Access Channel, Broadcast Channel, Encoding of Correlated Sources. **Course Reference**: 1. Thomas M. Cover, Joy A. Thomas; Elements of Information Theory, 2nd Edition , John Wiley & Sons, 2006; 2. James L. Massey, Lecture notes on Applied Digital Information Theory; 3. Robert G. Gallager, Information Theory and Reliable Communication, John Wiley & Sons, 1968; 4. David J.C. MacKay, Information Theory, Inference, and Learning Algorithms,Cambridge University Press; 5. Robert Ash, Information Theory;, Dover Publications, 1965; 6. Raymond W. Yeung,Information Theory and Network Coding, Springer, 2006; 7. Abbas El Gamal and YoungHan Kim, Network Information Theory, Cambridge University Press, 2012; 8. I. Csiszar and J. Korner,Information Theory: Coding Theorems for Discrete Memoryless Systems, 2nd edition, Cambridge Univ. Press; 9. Papers from IEEE Transactions on Information Theory.
EE667A	INFORMATION THEORY	3-0-0-0-9	Introduction: Entropy, Relative Entropy, Mutual Information Inequalities, Entropy rate. Ansymptotic Equipartition Property (AEP): Consequences of the AEP, Typical Sequences, Shannon McMillanBreiman Theorem. Data Compression: Block to variable lenght codes, ShannonFano code, Huffman code, variable to fixed lenght coding Tunstal code, variable to variable length codes/ arithmetic code. Channel capacity: Discrete Memoryless Channel, Joint Typicality, Channel Coding Theorem and its converse, Feedback capacity, Source Channel Separation Theorem. Differential Entropy: Difinition, Properties. Gaussian Channel: Definition, Parallel Gaussian Channels, Channels with Colored Gaussian Noise, Gaussian Channels with Feedback. Rate Distortion Theory: Rate Distortion Function, Rate Distortion theorem and its converse, BlahutArimoto

			Algorithm. Universal Source Coding: Universal codes, LempelZiv codes; LZ 78, LZW, Slinding Window Lempel Ziv algorithm (LZ77). Network Information Theory: Gaussian MultiUser Channels, Multiple Access Channel, Broadeast Channel, Encoding of Correlated Sources. **Course Reference:** 1. Thomas M. Cover, Joy A. Thomas, Elements of Information Theory, 2nd Edition , John Wiley & Sons, 2006; 2. James L. Massey, Lecture notes on, Applied Digital Information Theory; 3. Robert G. Gallager, Information Theory and Reliable Communications, John Wiley & Sons, 1968; 4. David J.C. MacKay, Information Theory, Inference, and Learning Algorithms, Cambridge University Press; 5. Robert Ash, Information Theory,Dover Publications, 1965; 6. Raymond W. Yeung, Information Theory and Network Coding, Springer, 2006; 7. Abbas El Gamal and YoungHan Kim, Network Information Theory.Cambridge University Press, 2012; 8. I. Csiszar and J. Korner, ;Information Theory: Coding Theorems for Discrete Memoryless Systems 2nd edition, Cambridge Univ. Press; 9. Papers from IEEE Transactions on Information Theory.
EE668	CODING THEORY	3-0-0-0-9	1.Introduction: Types of codes, channel models, maximum likelihood decoding, Shannon's noisy channel coding theorem, FEC, ARQ, HARQ; 2. Linear Blaock Codes: Generator matrix, parity check matrix, syndrome, error detection, error correction, minimum distance of the code, dual code, weight enumeration and Mac Williams theorem. Examples of simple linear block codes; 3. Some linear block codes: Construction, properties and decoding of some popular block codes; Hamming codes, Reed Muller codes; 4. Bonds on codes: Hamming bound, Plotkin bound, Singleton Bound, Elias Bound, GilbertVarshmov Bound, Linear programming bounds; 5. New codes from old codes: Extending a code, puncturing a code, expunging a code, augmenting a code, shortening a code, direct sum construction. **Course Reference**: 1. Shu Lin and Daniel J. Costello, Jr; Error Control Coding, second ed., Prentice Hall, 2004; 2. F.J. Mac Williams, N.J.A. Sloance;The Theory of Error Correcting Codes, NorthHolland, Amsterdam, 1977; 3. R.E. Blahut, Algebraic Codes for Data Transmission, 1st Ed., Cambridge Univ. Press 2003; 4. Todd K. Moon, Error Correction Coding, 1st Ed., WileyInter science, 2006; 5. Cary W. Huffman, Vera Pless; Fundamentals of ErrorCorrecting Codes,1st Edi. Cambridge Univ. Press, 2003; 6. Ezio Biglieri; Coding for Wireless Channels, Springer, 2005; 7. Tom Richardson and Rudiger Urbanke; Modern Coding Theory, Cambridge Univ. Press, 2008; 23.09.14
EE668A	CODING THEORY	3-0-0-0-9	1.Introduction: Types of codes, channel models, maximum likelihood decoding, Shannon's noisy channel coding theorem, FEC, ARQ, HARQ; 2. Linear Blaock Codes: Generator matrix, parity check matrix, syndrome, error detection, error correction, minimum distance of the code, dual code, weight enumeration and Mac Williams theorem. Examples of simple linear block codes; 3. Some linear block codes: Construction, properties and decoding of some popular block codes; Hamming codes, Reed Muller codes; 4. Bonds on codes: Hamming bound, Plotkin bound, Singleton Bound, Elias Bound, GilbertVarshmov Bound,

			Linear programming bounds; 5. New codes from old codes: Extending a code, puncturing a code, expunging a code, augmenting a code, shortening a code, direct sum construction. **Course Reference:** 1. Shu Lin and Daniel J. Costello, Jr, Error Control Coding, second ed., Prentice Hall, 2004; 2. F.J. Mac Williams, N.J.A. Sloance; The Theory of Error Correcting Codes, North Holland, Amsterdam, 1977; 3. R.E. Blahut, Algebraic Codes for Data Transmission,1st Ed., Cambridge Univ. Press 2003; 4. Todd K. Moon; Error Correction Coding, 1st Ed., WileyInter science, 2006; 5. Cary W. Huffman, Vera Pless; Fundamentals of ErrorCorrecting Codes, 1st Edi. Cambridge Univ. Press, 2003; 6. Ezio Biglieri, Coding for Wireless Channels, Springer, 2005; 7. Tom Richardson and Rudiger Urbanke Modern Coding Theory, Cambridge Univ. Press, 2008; 23.09.14
EE669	SIMULATION OF COMMUNICATION SYSTEMS	3-0-0-0-9	Introduction to simulation. Discrete time signals and systems. Modeling linear time invariant system. Modeling linear time varying system. Modeling memoryless nonlinear systems. Modeling nonlinear system with memory. Nonlinear differential equation models. Review of probability and randon processes. Monte Carlo simulation and randon number generation. Testing of random number generators. Modeling of functional blocks in communication systems. Wireless fading channel models. Discrete Markov fading channel models. Estimation of parameters in simulation. Estimation of performance measures from simulation. Importance sampling. Other performance estimation methods. Variance reduction techniques. Simulation optimization. Case Study. **Course Reference:** 1. P. Balaban, K.S. Shanmugan, and B.W. Stuck, eds., ComputerAided Modeling, Analysis, and Design of Communication Systems, vol. 6, IEEE Journal on Selected Areas in Communications, Jan. 1984; 2. P. Balaban, E. Biglieri, M.C. Jeruchim, H.T. Mouftah, C.H. Sauer, and K.S. Shanmugan, eds., ComputerAided Modeling, Analysis, and Design of Communication Systems II, vol. 6, IEEE Journal on Selected Areas in Communications, Jan. 1988; 3. J.K. Townsend, A.F. Elrefaic, H. Meyr, and M. Pent, eds., ComputerAided Modeling, Analysis, and Design of Communication Links, vol.11, IEEE Journal on Selected Areas in Communications Apr. 1993; 4. K.S. Shanmugan, eds., Simulation and Implementation of Communication and Signal Processing Systems, vol. 32, IEEE Communication Magazine, July 1994; 23.09.14
EE669A	SIMULATION OF COMMUNICATION SYSTEMS	3-0-0-0-9	Introduction to simulation. Discrete time signals and systems. Modeling linear time invariant system. Modeling linear time varying system. Modeling memoryless nonlinear systems. Modeling nonlinear system with memory. Nonlinear differential equation models. Review of probability and randon processes. Monte Carlo simulation and randon number generation. Testing of random number generators. Modeling of functional blocks in communication systems. Wireless fading channel models. Discrete Markov fading channel models. Estimation of parameters in simulation. Estimation of performance measures from simulation. Importance sampling. Other performance estimation methods. Variance reduction techniques. Simulation

			optimization. Case Study. **Course Reference**: 1. P. Balaban, K.S. Shanmugan, and B.W. Stuck, eds., Computer Aided Modeling, Analysis, and Design of Communication Systems, vol. 6, IEEE Journal on Selected Areas in Communications, Jan. 1984; 2. P. Balaban, E. Biglieri, M.C. Jeruchim, H.T. Mouftah, C.H. Sauer, and K.S. Shanmugan, eds., Computer Aided Modeling, Analysis, and Design of Communication Systems II, vol. 6, IEEE Journal on Selected Areas in Communications, Jan. 1988; 3. J.K. Townsend, A.F. Elrefaic, H. Meyr, and M. Pent, eds., ComputerAided Modeling, Analysis, and Design of Communication Links, vol.11, IEEE Journal on Selected Areas in Communications Apr. 1993; 4. K.S. Shanmugan, eds., Simulation and Implementation of Communication and Signal Processing Systems, vol. 32, IEEE Communication Magazine, July 1994. 23.09.14
EE670	WIRELESS COMMUNICATIONS	3-0-0--4	Introduction to Wireless Communications, multipatchannel models, capacity of wireless channels, performance of digital modulation techniques over wireless channels, combining techniques, multicarrier modulation, coding for wireless channels, overview of current wireless standards, MIMO techniques. **Course Reference**: 1. Wireless Communications: Principles and Practice by TS Rappaport, PrenticeHall, second edition, 2002; 2. Principles of Mobile Communications by GL Stuber, Kluwer Academic, second edition, 2001; 3. Wireless Communications by AJ Goldsmith, Cambridge University Press; 4. Multiuser Detection by S Verdu, Cambridge University Press, 1998; 5. Modern Wireless Communications by S Haykin and MMoher, PrenticeHall, 2004.
EE670A	WIRELESS COMMUNICATIONS	3-0-0-0-9	Introduction to Wireless Communications, multipatchannel models, capacity of wireless channels, performanc of digital modulation techniques over wireless channels, combining techniques, multicarrier modulation, coding for wireless channels, overview of current wireless standards, MIMO techniques. **Course Reference**: 1. Wireless Communications: Principles and Practice by TS Rappaport, Prentice Hall, second edition, 2002; 2. Principles of Mobile Communications by GL Stuber, Kluwer Academic, second edition, 2001; 3. Wireless Communications by AJ Goldsmith, Cambridge University Press; 4. Multiuser Detection by S Verdu, Cambridge University Press, 1998; 5. Modern Wireless Communications by S Haykin and MMoher, PrenticeHall, 2004.
EE671	NEURAL NETWORKS	3-0-0--4	Theory of representation; Two computational pradigms; Multilayer networks; Autoassociative and hetero associative nets; Learning in neural nets: Supervised and unsupervised learning; Application of neural nets; Neural network simulators.
EE671A	NEURAL NETWORKS	3-0-0-0-9	Theory of representation; Two computational pradigms; Multilayer networks; Auto associative and hetero associative nets; Learning in neural nets: Supervised and unsupervised learning; Application of neural nets; Neural network simulators.
EE673	DIGITAL COMMUNICATION	3-0-0--4	OSI model, queueing theory, physical layer, error detection and correction, data link layer, ARQ strategies, framing, media

	NETWORKS		access layer, modelling and analysis of important media access control protocols, FDDI and DQDB MAC protocols for LANs and MANs, network layer, flow control & routing, TCP/IPprotocols, ATM.
EE673A	DIGITAL COMMUNICATION NETWORKS	3-0-0-0-9	OSI model, queueing theory, physical layer, error detection and correction, data link layer, ARQ strategies, framing, media access layer, modelling and analysis of important media access control protocols, FDDI and DQDB MAC protocols for LANs and MANs, network layer, flow control & routing, TCP/IP protocols, ATM.
EE677	KNOWLEDGE BASED MAN MACHINE SYSTEMS	3-0-0--4	Knowledge representation, statespace techniques, logic, semantic networks, frames, script. Production system, object oriented and ANN models. Applications in robotic vision and processing of documents, natural languages and speech. Course Project involving extensive programming is compulsory. Combinational and sequential circuits, Logic families, Number systems, Arithmetic circuits using SSI/MSI chips. Basic microprocessor architecture, Essentials ofa microcomputer system, Instruction sets, Machine cycles, Interrupt structures. Parallel /serial I/O, Analog I/O, DMA operation. Peripheral controllers.
EE678A	POWER MANAGEMENT CIRCUITS	3-0-0-0-9	Introduction to Motivation. Solar Radiations: Composition, spectrum Air Mass, optimal angle of panel, solar constant, Indias solar resource. Solar PV cell: Direct vs Indirect Band, Generation of carriers, drift and diffusion currents, PN Junction, IV characteristics of cell, fill factor, maximum short circuit current, maximum open circuit voltage, efficiency, fundamental and technological losses, electrical model of cell, effect of series and shunt resistances, optical losses and minimization techniques, Soloar PV Module: Series/parallel connection, IV characteristics of module, mismatching due to temperature and shading, Bypass and blocking diodes, overview of PV module fabrication, IV equation of module, standard test conditions, Review of dcdc buck & boost converters Maximum power point tracking: motivation, power extracted with resistive load, implementing variable resistance load, tracking using dcdc converter, direct vs indirect control, fractional open circuit voltage control, hill climbing method and issues, incremental conductance method, mppt extraction efficiency, effect of voltage ripple on efficiency. Battery charging: types and characteristics of battery, comparison of charging characteristics, popular technique for charging lead acid battery, charging using dcdc converter, PV charging circuits, stable operation of chargers. Solar Inverters: standalone vs grid connected, days of autonomy, payback period, Parity, grid feeding inverter, central inverters circuits, string inverters, earth leakage current, module inverters, features of grid feeding inverter, relevant standards, islanding. **Course Reference**: 1.Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications, Prentice Hall of India, 2011; 2. N. Mohan, T.M. Undeland & W.P. Robbins, Power Electronics: Converter, Applications & Design, John Wiley & Sons, 1989; 3. Chenming Calvin Hu, Moden Semiconductor Devices ofr Integrated Circuits, Prentice Hall,

			2009 (Chapters1, 2 and 4); 4. Chenming Hu and Richard M White, Solar Cells: From basics to advanced systems, McGraw Hill Book Company, 1983 (Section 3, 7 and 3.8); 5. Antonio Luque and Steven Hegedus, Handbook of Photovoltaic Science and Engineering, John Wiley & Sons Ltd, 2010; 6. Erickson and Maksimovic, Fundamentals of Power Electronics, Springer, 2001 (Chapter 2, 3, 5 and 6); 7. T. Esram and P.L. Chapman, Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques, IEEE Trans, Energy Conversion, Vol.22, no.2, pp.439449, June 27. 24-MAR-15
EE679	QUEUEING SYSTEMS	3-0-0--4	Review of probability and stochastic processes, Markov chains, Littles theorem, modelling & analysis of M/M/ queues, Burkes Theorem, Reversibility, Methodof stages, Analysis of M/G/1 queues, Queues with vacations, Work conservation principle, Priority queues, Queues served in cyclic order, Fluidflow and diffusion approximations.
EE680	INTELLIGENT INSTRUMENTATION	2-3-0--4	Introduction, data flow and graphical programming techniques, Virtual instrumentation (VI), advantages, VIs and SubVIs, Data acquisition methods, DAQ hardware, PC hardware; Structure, Operating system, ISA, PCI, USB, PCMICAbuses, Instrumentation buses. IEEE 488.1 and
EE680A	INTELLIGENT INSTRUMENTATION	2-0-3-0-9	Introduction, data flow and graphical programming techniques, Virtual instrumentation (VI), advantages, VIs and SubVIs, Data acquisition methods, DAQ hardware, PC hardware; Structure, Operating system, ISA, PCI, USB, PCMICAbuses, Instrumentation buses. IEEE 488.1 and
EE681	COMPACT MODELING	3-0-0-0-9	Introduction to Simulation. Introduction to SPICE and Compact Modeling. Integrated Resistor Modeling. Integrated MOS Varactor Modeling. MOSFET Modeling approaches: Threshold Voltage based modeling (BSIM3, MSIM4), Charge based modeling (BSIM6, EKV), Surface Potential based modelling (PSP). Quality of MOSFET Compect Models and Benchmark Tests. Layout Effects and Parameter Extraction. High Frequency Effects and RF Modeling. SOI MOSFET Modeling. Noise Modeling. Multigate MOSFETs. C. Hu; Modern Semiconductor Devices for Integrated Circuits; Pearson/Prentice Hall, New Jersey.Compac Modeling: Priciples, Techniques and Applications by Gennady Gildenblat, Springer. MOSFET Models for SPICE Simulation: Including BSIM3v3 and BSIM4 by William Liu, Wiley IEEE Press.Chargebased MOS Transistor Modeling: The EKV Model for LowPower and RF IC Design by Christian C. Enz and Eric A. Vittoz, John Wiley & Sons.BSIM4 and MOSFET Modeling for IC Simulation by W. Liu and C. Hu, World Scientific Publishing Co. FinFETs and Other MultiGate Transistors (Integrated Circuits and Systems) by J.P. Coling (Editor).
EE681A	COMPACT MODELING	3-0-0-0-9	Introduction to Simulation. Introduction to SPICE and Compact Modeling. Integrated Resistor Modeling. Integrated MOS Varactor Modeling. MOSFET Modeling approaches: Threshold Voltage based modeling (BSIM3, MSIM4), Charge based modeling (BSIM6, EKV), Surface Potential based modelling (PSP). Quality of MOSFET Compect Models and Benchmark Tests. Layout Effects and Parameter Extraction. High Frequency Effects and RF Modeling. SOI MOSFET Modeling. Noise

			Modeling. Multigate MOSFETs. C. Hu; Modern Semiconductor Devices for Integrated Circuits; Pearson/Prentice Hall, New Jersey.Compac Modeling: Priciples, Techniques and Applications by Gennady Gildenblat, Springer. MOSFET Models for SPICE Simulation: Including BSIM3v3 and BSIM4 by William Liu, Wiley IEEE Press.Charge based MOS Transistor Modeling: The EKV Model for LowPower and RF IC Design by Christian C. Enz and Eric A. Vittoz, John Wiley & Sons. BSIM4 and MOSFET Modeling for IC Simulation by W. Liu and C. Hu, World Scientific Publishing CoFinFETs and Other Multi Gate Transistors (Integrated Circuits and Systems) by J.P. Coling (Editor). 24.09.14
EE682	GAME THEORY FOR WIRELESS COMMUNICATIONS	3-0-0-0-4	Introduction: Games with Perfect Information (Theory with examples) 1. Brief Revision ofNormal Games, Nash Equilibrium, Utility Theory; 2. Mixed Strategies; 3. Introduction to Basics of Wireless Communications; 4. Fading Channels and Diversity ;5. BitError Rate Calculation for Wireless Communications; 6. CDMA, OFDM and MIMO technologies in Wireless; 7. Wireless Sensor Networks; 8. Supermodular and Potential Games and applications in CDMA wireless communications. Applications 1. Market Equilibrium and Pricing 7; 2. Auctions for Wireless Spectrum; 3. Wireless Networks: Introduction to Basics of Wireless; 4. Resource Allocations in Wireless; 5. Admission Control, Routing in Sensor and AdHoc Networks; 6. Modeling Network Traffic and Strategic Network Formation; 7. Electoral Competitions and applications in Wireless Sensor Networks Games with Imperfect Informational. Bayesian Games, Extensive Games with Imperfect Information Application I. Auctions: Radio Spectrum, With Arbitrary Distribution of Valuations 6; 2. Signaling Games Nash Bargaining with Applications(I). Rubinstein Bargaining Model with Alternating Offers; 2. Nash Bargaining Solution 63. Relation of Axiomatic and Strategic Model; 4. Bargaining in Wireless Network.Auctions [Ill] and Mechanism Design with Applications1. Revenue Equivalence. Mechanism and Optimal Mechanisms for Wireless3. Efficient Mechanism: VickreyClarkeGroves Auction for Wireless 124. Application of VCG in Resource Allocation for Wireless; 5. Dynamic Spectrum Auction in Cognitive Radio Networks; 6. Mechanisms in Networking and Wireless; 7. Applications and Case Studies in Wireless
EE683A	QUANTUM AND WAVE PHENOMENA	3-0-0-0-9	1. Introduction to quantum mechanics and its tools: Motivation for quantum mechanics: early experiments; general principles of quantum mechanics: operator algebra, eigenstates, superposition, observables and expectation values, uncertainty relations, commutators, angular momentum, Dirac notation; potential wells and barriers, harmonic oscillator, Hydrogenic atom; time independent and dependent perturbation theory. 2. Device applications of quantum and wave phenomena: Density of states; practical examples of low dimensional systems such as quantum wells, wires and dots: design, fabrication and characterization techniques; engineered electronic and optical properties of these low dimensional materials; application in electronic, optoelectronic and photonic devices; current research efforts towards using quantum mechanical effects for developing

			efficient devices. **Course Reference**: 1. R.L. Liboff, Introductory Quantum Mechanics (Addison Wesley); 2. A. Yariv, An Introduction to Theory and Applications of Quantum Mechanics (John Wiley & Sons); 3. S. Gasiorowicz, Quantum Physics (Wiley); 4. D.J. Griffiths, Introduction to Qauntum Mechanics (Pearson Prentice Hall); 5. J.H. Davies, The Physics of Low dimensional Semiconductors (Cambridge University Press). 07-OCT-2015
EE684A	FIBER-OPTIC COMMUNICATIONS	3-0-0-0-9	1. Introduction. 2. Light propagation in optical fibers. Single and multimode fibers, light guiding by fibers, material and waveguide dispersion, Polarization mode dispersion, Nonlinear effects: self and cross phase modulation, Raman and Brillouin scattering, four wave-mixing etc. 3. Optical transmitters and modulation. External modulators: phase and intensity, bias control, Pulse shaping, pulse carving, Modulation formats Intensity modulation, RZ and NRZ amplitude modulation, Mary modulation using MachZehnder modulator, MSK, IQ modulation and optical OFDM. 4. Detection of optical signals. Direct detection: receiver structure, data recovery, signal to noise ratio, performance calculations for binary digital optical systems. Coherent detection: heterodyne, homodyne, DSP assisted coherent optical receiver, performance analysis. 5. Optical amplifiers. Principles of SOA and EDFA, single and double pump configurations, ASE noise in SOA and EDFA, OSNR calculations. 6. Optical link design. Power budget under linear and nonlinear effects, power penalty, dispersion tolerance in DWDM systems. **Course Reference**: 1. M. Cvijetic and I.B. Djordjevic, Advanced optical communication systems and networks, Artech House, 2013; 2. S. Kumar and M.J. Deen, Fiberoptic communications: Fundamentals and applications, Wiley, 2014. 07-OCT-2015
EE685A	SEMICONDUCTOR OPTICAL COMMUNICATION DEVICES	3-0-0-0-9	1. Introduction. 2. Review of Semiconductors. 3. Epitaxial Growth of Semiconductors. 4. Semiconductor Optical Waveuides. 5. LED. 6. Diode Lasers. 7. Fabrication and Packaging. 8. Single mode Laser diodes plus Reliability. 9. PhotoDetectors. 10. External Modulators. 11. Photonic Integrations. **Course Reference**: 1. Modular Series on Solid State Devices, Vol. VI, Ed: G.W. Neudek & R.F Pierret: R.F. PIERRET, Addision Wesley; 2. Optical Fiber Communication Systems: W.B. JONES, HRW (1988); 3. Semiconductor Optoelectronic Devices: P.K. BHATTACHARYA, Prentice Hall; 4. Elements of Optoelectronics and Fiber Optics: C.L. CHEN, Irwin; 5. Handbook of Semiconductor Lasers and Photonic Integrated Circuits: Y. SUEMATSU & A.R. ADAMS, Chapman & Hall; 6. Optical Electronics in Modern Communication: A. YARIV, Oxford University Press; 7. Semiconductor Devices for HighSpeed Optoelectronics: GIOVANNI GHIONE, Cambridge Univ. Press. 07-OCT-2015
EE686	MICROWAVE IMAGING CHARACTERIZATIO N AND NONDESTRUCTIVE	3-0-0-0-4	I. Introduction to electromagnetic theory and microwaves; review of Maxwell's equations, interaction of microwaves with the dielectric materials and the concept of effective permittivity, definition of microwave imaging, characterization and testing, the concept of using microwaves as the imaging and testing tool;

	TESTING		basic parameters required for themicrowave imaging and their practical equivalents. 2. Review of transmission line theory and the equivalent network representation of field quantities at microwave frequencies, scattering parameters and the transmission matrix, the relationship between the scattering and transmission matrices. 3. Electromagnetic scattering theory: direct and inverse problems, the inverse problem from the mathematic point of view, basis of the electromagnetic scattering problem formulation for the microwave characterization and imaging applications. 4. Overview of the microwave methods for the material characterization and testing, resonant methods, cavity perturbation approach, reflection methods, transmission reflection methods. 5. Theory of transmission reflection methods for determining the permittivity and permeability of materials, various available algorithms, analytical approach, numerical optimization methods, formulation for the dispersive and anisotropic media. 1.2.3.4.5. **Course Reference**: 1.Jaleel Akhtar, Microwave Imaging: Reconstruction of One Dimensional Permittivity Profiles,Vdm Verlag Dr. Mueller, Germany, 2008; 2.L.F. Chen, C.K. Ong, C.P. Neo, V.V. Vardhan and V.K. Verdhan, Microwave Electronics:Measurement and Materials Characterization, John Wiley & Sons, 2004; 3.K.I. Hopcraft and P.R. Smith, Introduction to Electromagnetic Inverse Scattering, Kluwer Academic Publishers, The Netherlands, 1992; 4. Matteo Pastorino, Microwave Imaging, John Wiley & Sons, 2010; 5.Literature from various Journals relevant to specific topics.
EE686A	MICROWAVE IMAGING CHARACTERIZATIO N AND NONDESTRUCTIVE TESTING	3-0-0-0-9	I. Introduction to electromagnetic theory and microwaves; review of Maxwell's equations ,interaction of microwaves with the dielectric materials and the concept of effective permittivity, definition of microwave imaging, characterization and testing, the concept of using microwaves as the imaging and testing tool; basic parameters required for the microwave imaging and their practical equivalents; 2. Review of transmission line theory and the equivalent network representation of field quantities at microwave frequencies, scattering parameters and the transmission matrix, the relationship between the scattering and transmission matrices; 3. Electromagnetic scattering theory: direct and inverse problems, the inverse problem from the mathematic point of view, basis of the electromagnetic scattering problem formulation for the microwave characterization and imaging applications; 4. Overview of the microwave methods for the material characterization and testing, resonant methods, cavity perturbation approach, reflection methods, transmission reflection methods; 5. Theory of transmission reflection methods for determining the permittivity and permeability of materials, various available algorithms, analytical approach, numerical optimization methods, formulation for the dispersive and anisotropic media. 1.2.3.4.5. **Course Reference**: 1.Jaleel Akhtar, Microwave Imaging: Reconstruction of One Dimensional Permittivity Profiles,Vdm Verlag Dr. Mueller, Germany, 2008; 2.L.F. Chen, C.K. Ong, C.P. Neo, V.V. Vardhan and V.K. Verdhan, Microwave Electronics: Measurement and Materials Characterization, John Wiley &

			Sons, 2004; 3.K.I. Hopcraft and P.R. Smith, Introduction to Electromagnetic Inverse Scattering, KluwerAcademic Publishers, The Netherlands, 1992; 4.Matteo Pastorino, Microwave Imaging, John Wiley & Sons, 2010; 5.Literature from various Journals relevant to specific topics.
EE698D	SMART GRID TECHNOLOGY	3-0-0-0-4	Solar radiations, solar PV modules, maximum power point tracking, partial shading, leakage currents, grounding techniques, panel optimizers, grid integration issues, module integrated inverters, standalone inverters and battery charge controllers.
EE698F	RF MICROELECTRONIC S	3-0-0--9	Solar radiations, solar PV modules, maximum power point tracking, partial shading, leakage currents, grounding techniques, panel optimizers, grid integration issues, module integrated inverters, standalone inverters and battery charge controllers.
EE699	M TECH THESIS	-0-0--	M. Tech. Thesis
EE699.	M TECH THESIS (FOR DUAL DEGREE ONLY)	0----9	M TECH THESIS (FOR DUAL DEGREE ONLY)
EE705	INTELLIGENT SYSTEMS & CONTROL	3-0-0-0-4	Norms of Signals, Vectors and Matrices,Positive Definite Functions, Positive Definite Matrices; Continuous time Statespace Model, LTI Statespace Model, Nonlinear Statespace model, Equilibrium point and Linearization using first order Taylor series, Linearization technique for operating points other than origin; Lyapunov Stability Theory, Lyapunov stability of time invariant system, LaSalle's Invariance Theorem, Chetaev's Instability Theorem, Lyapunov stability of time varying system, Lyapunov's indirect method, Lyapunov stability for linear systems; Discretetime Systems, Discrete time LTI Statespace Model, Discretetime Nonlinear Statespace model, ARMAX and NARMAX Models, Lyapunov Stability for Discrete Time Systems; Modeling of Different Nonlinear Systems: Inertial Wheel Pendulum, Two Link Manipulator, Inverted Pendulum Mounted on A Cart, Induction Motor; Nonlinear Control Strategies: Feedback Linearization, Back stepping Design, State feedback linearizable systems.FeedForward Networks: Multilayered Neural Networks, Radial Basis Function Networks. Adaptive Learning Rate; Feedback Networks, Back Propagation Through Time (BPTT), Real Time Recurrent Learning (RTRL); Kohonen Self Organizing Map; System Identification Using Neural Networks Classical sets, Fuzzy Sets, Concept of a fuzzy number, Operations on Fuzzy sets, Properties of Fuzzy Sets, Some Typical Membership Functions; Extension Principle of Fuzzy Sets, Crisp Relation, Fuzzy Relations, Projection of Fuzzy Relations, Cylindrical Extension of Fuzzy Relations, Relation Inference; FUzzy Rule Base and Approximate Reasoning, Fuzzy Linguistic Variables, Linguistic modifier, Rule base systems, Fuzzy Rulebase, Fuzzy Implication Relations, Fuzzy Compositional Rules, Inference mechanism compared, Approximate Reasoning; Fuzzy Logic Control (FLC), Mamdani Model, Takagi Sugeno (TS) Fuzzy Model; System Identification Using TS Fuzzy Models,The TS Model From InputOutput Data, The TS Fuzzy Model Using Linearization.

			Course Reference: 1. Alexander M. Meystel and James S. Albus, Intelligent Systems: Architecture, Design, Control, WileyInterscience, 2001; 2. Pedro Ponce Cruz and Fernando D. Ramirez Figueroa, Intelligent Control Systems with LabVIEW (TM), Springer, 2009.
EE705A	INTELLIGENT SYSTEMS & CONTROL	3-0-0-0-9	Norms of Signals, Vectors and Matrices,Positive Definite Functions, Positive Definite Matrices; Continuous time Statespace Model, LTI Statespace Model, Nonlinear Statespace model, Equilibrium point and Linearization using first order Taylor series, Linearization technique for operating points other than origin; Lyapunov Stability Theory, Lyapunov stability of time invariant system, LaSalle's Invariance Theorem, Chetaev's Instability Theorem, Lyapunov stability of time varying system, Lyapunov's indirect method, Lyapunov stability for linear systems; Discretetime Systems, Discretetime LTI Statespace Model, Discretetime Nonlinear Statespace model, ARMAX and NARMAX Models, Lyapunov Stability for Discrete Time Systems; Modeling of Different Nonlinear Systems: Inertial Wheel Pendulum, Two Link Manipulator, Inverted Pendulum Mounted on A Cart, Induction Motor; Nonlinear Control Strategies: Feedback Linearization, Back stepping Design, State feedback linearizable systems. Feed Forward Networks: Multilayered Neural Networks, Radial Basis Function Networks. Adaptive Learning Rate; Feedback Networks, Back Propagation Through Time (BPTT), Real Time Recurrent Learning (RTRL); Kohonen Self Organizing Map; System Identification Using Neural Networks Classical sets, Fuzzy Sets, Concept of a fuzzy number, Operations on Fuzzy sets, Properties of Fuzzy Sets, Some Typical Membership Functions; Extension Principle of Fuzzy Sets, Crisp Relation, Fuzzy Relations, Projection of Fuzzy Relations, Cylindrical Extension of Fuzzy Relations, Relation Inference; FUzzy Rule Base and Approximate Reasoning, Fuzzy Linguistic Variables, Linguistic modifier, Rulebase systems, Fuzzy Rulebase, Fuzzy Implication Relations, Fuzzy Compositional Rules, Inference mechanism compared, Approximate Reasoning; Fuzzy Logic Control (FLC), Mamdani Model, TakagiSugeno (TS) Fuzzy Model; System Identification Using TS Fuzzy Models,The TS Model From InputOutput Data, The TS Fuzzy Model Using Linearization. **Course Reference**: 1. Alexander M. Meystel and James S. Albus, Intelligent Systems: Architecture, Design, Control, WileyInterscience, 2001; 2. Pedro Ponce Cruz and Fernando D. Ramirez Figueroa, Intelligent Control Systems with LabVIEW (TM), Springer, 2009.
EE799	PHD THESIS	-0-0--	Ph. D. Thesis
ESC102N	INTRODUCTION TO ELECTRONICS	3-1-3-0-5	Stored program concept (with simple computer simulator), machine language and instruction formats, assembly language for the simple computer. Integer representation, finite representation of real numbers, overflow, underflow, errors due to finite representations. Expressions, values and variables, types, lvalue, rvalue, unary, binary, ternary operations. Conditionals, ifthen, if then else, nested conditionals, switchcase. Loops, for, while, repeat, loopinvariants,

			precondition, postcondition. Functions and return values, arguments, passbyvalue, effect of passing pointers (like pass by reference). Recursion. Arrays, enums, searching, sorting. Pointers, lists, dynamic data structures, stack, queue, graphs, trees related algorithms, memory and its management. Elementary complexity motivation, concrete complexity, big O notation. Linux tools, introduction to shell programming. Elementary numerical problem solving will addressed largely through some labs e.g. root finding, solutions of systems of linear equations, integration, solution of ODEs. **Course Reference:** 1. Brian W Kernighan and Dennis M Ritchie, The C Programming Language,2nd Ed. ANSI C version, Pearson, 2006.
ESC201A	INTRODUCTION TO ELECTRONICS	3-1-3-0-14	Circuit analysis techniques (nodal, mesh, superposition, Thevenins, and Nortons theorems); Transient analysis of capacitive and inductive circuits; Sinusoidal steadystate analysis of circuits containing resistors, capacitors, and inductors; Transfer functions andfrequency response; Semiconductors; Diodes and diode circuits; MOSFETs and amplifiers; IC fabrication; Operational amplifier circuits and waveform generators; Number system, logic gates,logic minimization, combinational circuits; Field programmable gate arrays (FPGAs); Flipflops, sequential circuits, counters, shift registers; data converters (DAC, ADC).
ESO203A	INTRODUCTION TO ELECTRICAL ENGINEERING	3-1-2-0-13	Introduction to Single Phase Circuits, Power Calculations, Magnetic Circuits,Mutually Coupled Circuits, Transformers, Equivalent Circuit and Performance, Analysis of Three Phase Circuits, Direct Current Machines: Construction, Equivalent Circuit, Torque Speed Characteristics, Applications; Induction Machines:Construction Equivalent Circuit, Torque speed Characteristics, Speed Control, Starting, Applications Synchronous Machines: Construction, Equivalent Circuit,Generator & Motor Operation Power Angle Characteristics, Hunting, PullOut,Stepper Motors and controls, Principles of Industrial Power Distribution.
ESC102N	INTRODUCTION TO ELECTRONICS	3-1-3-0-5	Stored program concept (with simple computer simulator), machine language and instruction formats, assembly language for the simple computer. Integer representation, finite representation of real numbers, overflow, underflow, errors due to finite representations. Expressions, values and variables, types, lvalue, rvalue, unary, binary, ternary operations. Conditionals, if then, if then else, nested conditionals, switchcase. Loops, for, while, repeat, loop invariants, pre-condition, post condition. Functions and return values arguments, pass by value, effect of passing pointers (like pass by reference). Recursion. Arrays, enums, searching, sorting. Pointers, lists, dynamic data structures, stack, queue, graphs, trees related algorithms, memory and its management. Elementary complexity motivation, concrete complexity, big-notation. Linux tools, introduction to shell programming. Elementary numerical problem solving will addressed largely through some labs e.g. root finding, solutions of systems of linear equations, integration, solution of ODEs. **Course Reference:** 1. Brian W Kernighan and Dennis M

			Ritchie, The C Programming Language,2nd Ed. ANSI C version, Pearson, 2006.
ESC201A	INTRODUCTION TO ELECTRONICS	3-1-3-0-14	Circuit analysis techniques (nodal, mesh, superposition, Thevenins, and Nortons theorems); Transient analysis of capacitive and inductive circuits; Sinusoidal steady state analysis of circuits containing resistors, capacitors, and inductors; Transfer functions andfrequency response; Semiconductors; Diodes and diode circuits; MOSFETs and amplifiers; IC fabrication; Operational amplifier circuits and waveform generators; Number system, logic gates,logic minimization, combinational circuits; Field programmable gate arrays (FPGAs); Flipflops,sequential circuits, counters, shift registers; data converters (DAC, ADC).
ESO203A	INTRODUCTION TO ELECTRICAL ENGINEERING	3-1-2-0-13	Introduction to Single Phase Circuits, Power Calculations, Magnetic Circuits, Mutually Coupled Circuits, Transformers, Equivalent Circuit and Performance, Analysis of Three Phase Circuits, Direct Current Machines: Construction, Equivalent Circuit, Torque Speed Characteristics, Applications; Induction Machines: Construction Equivalent Circuit, Torque speed Characteristics, Speed Control, Starting, Applications Synchronous Machines: Construction, Equivalent Circuit, Generator & Motor Operation Power Angle Characteristics, Hunting, PullOut,Stepper Motors and controls, Principles of Industrial Power Distribution.
ESO210	INTRODUCTION TO ELECTRICAL ENGINEERING	3-1-2-0-5	1. Introduction, SinglePhase Circuits, Power Calculations, Analysis of ThreenPhase Circuits,Mutually Coupled Circuits; 2. Transformers: Magnetic Circuits, Equivalent Circuit and Performance; 3. Direct Current Machines: Construction, Equivalent Circuit, Torque Speed Characteristics, Applications; 4. Induction Machines: Construction, Equivalent Circuit, Torque speed characteristics, Speed Control, Starting, Applications; 5. Synchronous Machines: Construction, Equivalent Circuit, Generator & Motor Operation, /,Power Angle Characteristics, Hunting, PullOut; 6. Special Topics: Industrial Power Distribution, HV cables Stepper Motors and controls,lLabomtmy Work: Nine experiments performed in the laboratory work cover the following. Power Circuit Measurements, Single Phase Transfonners, D.C Motor & Generator, Single Phase Induction Motor. **Course Reference**: 1. Electric Machines and Power Electronics P.C. Sen, Second Edition, Wiley; 2. Basic Electrical Engineering D. P Kothari & I J Nagrath, Tata McGraw Hill; 3. Electric Machines 2nd edition, D. P Kothari & I. J Nagrath, Tata McGraw Hill; 4. Electric Machinery, 4th/5thedition, A.E. Fitzgerald & C. Kingsley, Tata McGraw Hill

EARTH SCIENCE

EARTH SCIENCES

BS								TEMPLATE No. BS
	SEMESTER							
	1st	2nd	3rd	4th	5th	6th	7th	8th
C	MTH101A[11]	MTH102A[11]	ESC201A[14]	HSS-2(Level 1)[11]	**ESO204A**[11]	HSS-3(Level 2)[09]	HSS-4(Level 2)[09]	HSS-5(Level 2)[09]
O	PHY102A[11]/PHY103A[11]	PHY103A[11] /PHY102A(Lab)[11]	ESO213A[09]	**MSO-201A[11]**	ES411A[09]	ES413A[06]	ES417A[06]	ES418A[04]
U	PHY101A[03] /CHM101(Lab)[03]	CHEM101A[03]/PHY101A(Lab)[03]	**ESO-201A[11]**	TA202A[06]	ES412A[08]	ES414A[06]	DE-2[08-11]	DE-4[08-11]*
R	TA101A[09]	ESC101A[14]	TA201A[06]	ES312A[03]	ES400 [02]	ES415A[8]	DE-3[08-11]*	DE-5[08-11]*
	LIF101A[06]	CHM102A[08]	COM200[05]	ES313A[09]	DE-1 [09]	ES416A[08]	OE-3[09]	OE-5[09]
S E	ENG112A/HSS-1(Level-1)[11]	PE102A[03]	ES311A[11]	ES314A[09]	OE-1[09]	ES419A[06]	OE-4[09]/ UGP-3 [09] (ES393A)	OE-6[09]
S	PE101A[03]			ES315A[11]	UGP-1 [04] [ES391A] *(Extra Credits)*	OE-2[09]/ UGP-2(ES392A) [09]		UGP-4 [09] [ES394A] *(Extra Credits)*
	54	50	56	60	48	52	49-55	47-53

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	106	Credits
Department Elective (DE)	:	40	Credits
Open Elective (OE)	:	54	Credits
ESO/ SO	:	42	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	**415**	**Credits**

Basket A**
ES450 [09]
ES455[09]

REMARKS:

1) *The 8 credits shown against each OE in the template are only indicative. OE courses are available in 8-11 credits each. Students need to ensure that their total OE credits total up to AT LEAST 40.
2) **DE-1should be selected from Basket A.
3) UGP-1 and UGP-4 are optional courses and do not count towards graduation requirements, also do not count towards DE/OE credits.
4) UGP-2 & 3 are optional but if taken, OE credits may include 18 (9+9) credits of UGP-2 and UGP-3.
5) A student will be allowed to do UGP-3 only if s/he has done UGP-2.
6) Up to 36 OE credits may be waived for students opting either for Dual Degree or Double Major program.
7) Those students who decide to go for MS later after V Semester, and if they have taken UGPs 1 & 2, these UGPs will be adjusted as OE at the Department level.
8) Those who decide to go for MS should not do UGPs.
9) The field work for ES312A, ES414A, and ES418A will be conducted during the winter vacation period after the END Semester exam of respective ODD semester (e.g., III, V, and VII) but credits will be counted in the successive EVEN semester (i.e., IV, VI, and VIII). Therefore, students have to register for these courses for the respective EVENsemester.

BS-MS (PG Part – Category – A)*(from the same department)*					Template No. MS
	1st to 6th	7th	8th	9th	10th
C O U R S E S	COURSES AS DETAILED IN THE BS TEMPLATE	HSS-4(Level 2)[09]	HSS-5(Level 2)[09]	DEPG-1[08-11]*	MS PROJECT ES599
		ES417A[06]	ES418A[04]	DEPG -2[08-11]*	
		DE-2[08-11]	DE -4[08-11]	DEPG-3[08-11]*	
		DE-3[08-11]	DE -5[08-11]	DEPG-4[08-11]*	
		OE-3[09]	OE-5[09]	DEPG-5[08-11]*	
		OE-4[09]	OE-6[09]	MS Project [09] ES599	
		49-55	47-53	49-64	36

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION:

PG Component	:	40	Credits
MS Project	:	45	Credits

REMARKS:

1) *The 8 credits shown against each PGDE in the template are only indicative. PGDE courses are available in 8 – 11 credits each. Students need to ensure that their total PGDE credits total up to AT LEAST 40.
2) Course credits and Thesis credits mentioned under the dual degree template are only for the MS part of the program. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG program EXCEPT for credit waivers detailed above.
3) All courses to be taken with the permission of Supervisor/ DUGC Convener.
4) Those students who decide to go for MS later after V Semester, and if they have taken UGPs 2& 3, these UGPs will be adjusted as OE.
5) Those who decide to go for MS should not do UGPs.

DEPARTMENT OF ES			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
ES311A	CRYSTALLOGRAPHY AND MINERALOGY		Chemical and physical properties and identification of common rock forming (silicates, carbonates and oxides) minerals; crystallography, Unit cells, Crystal symmetry, classes and rotation. Systems, Plane and Bravais Lattices, Axial Ratios, Parameters, Miller Indices, Point Groups, Crystal

			Form, Zones, Crystal Habit, Stereographic Projection of Crystal Faces, Polymorphis and Pseudomorphs, Twinning; optical mineralogy, uniaxial, biaxial minerals; introductions to xray crystallography; crystal structures, chemistry, and origin nad significance of the rock forming minerals, Minearlogy of the Earth’s crusts, upper mantle, lower mantle and its Core. **Course Reference**: 1. Nasse, W. 2011. Introduction to Mineralogy (2 nd Ed.) Oxford University Press. 496 p; 2. Klein, C. & Dutrow, B. 2007. Manual of Mineral Science. Wiley. 716 p; 3. Putnis, A. 1992. An Introduction to Mineral Sciences Cambridge University Press. 480 p; 4. Sands, Donald (2012). Introduction to crystallography Courier Corporation; 5. Hammond, C. (2001). The basics of crystallography and diffractions, Oxford Science Publications; 6. Lovett, David (1999) Tensor properties of crystals, CRC Press. 11-MAR-2016
ES312A	FIELD GEOLOGY-I	0-0-3-0-3	This course will provide an introduction, to field work activities. How to use a Brunton Compass, reading of topographic maps, dip and strike measurements, and basics of lithological mapping. **Course Reference**: 1. Robert R. Compton, Geology in the Field. July, 1985; 2. Angela L. Coe, Geological Filed Techniques. October 25, 2010; 3. Richard J. Lisle, Peter Brabham, John W. Barnes, Basic Geological Mapping, 5th Edition August 2011. 11-MAR-2016
ES313A	GEOMORPHOLOGY AND EARTH SURFACE PROCESSES	3-0-0-0-9	Fundamental concepts of geomorphic system; Earth’s energy balance, global heat transfer, topography and bathymetry, liberation and flux of sediments, hydrological cycle and water budget. Guiding Principles of earth’s surface processes: Conservation, transport rules, event size and frequency; rates of processes and ages of landscapes. Whole Earth morphology and largescale topography; Exogenic and endogenic processes. The Surface water system: Drainage basins and river systems, river morphology and hydrology, hydraulic geometry and governing principles of open channel flow; river processes and landforms, river dynamics. The Groundwater system: Groundwater in hydrological cycle, groundwater flow and storage; chemistry of groundwater. The Atmospheric System: Atmospheric composition and mixing, atmospheric circulation, greenhouse effect. The Ocean and Coastal system: Coastal environment, waves, tides and currents. The relative movement of land and sea; coastal processes and landforms. Cryosphere growth and decay of ice sheets, controlling factors, Himalayan glaciers; Wind activity and geomorphic

			work, desertification and controlling factors. Global geomorphology and tectonics: Earth's physiography and landscape evolution; Landforms and tectonics of plate margins and plate interiors; Tectonic uplifts and denudation rates and controlling factors, Sea level change evidence, mechanism and effects; coupled tectonic surface process models. **Course Reference**: 1. Summerfield, S.A. (1991) Global Geomorphology, Longman; 2. Ernst, W.G. (2002) Earth Systems: Processes and Issues, Cambridge University Press; 3. Richards, K.S. (1982) Rivers: forms and processes in alluvial channels, Metheun; 4. Kale, V. and Gupta, Introduction to Geomorphology, Orient Longman; 5. Merrits, D, Dewet, A. and Menking, K. (1998) Environmental Geology; An earth system science approach. W.H. Freeman. 11-MAR-2016
ES314A	FUNDAMENTALS OF GEOPHYSICS	3-0-0-0-9	Introduction to geophysics, Earth as a planet and member of the solar system, origin and evolution of the Earth, Internal structure of the Earth; Concept of plate tectonics, plate motions and triple junctions; Gravitation, gravity anomalies and its variations, geoid, isostasy, rheology; Geomagnetic field, its origin and variations, paleomagnetism, and geomagnetic reversals; Introduction to seismology, seismic waves P, S and surface waves, seismograph, travel time curves and radial Earth structures, general properties of surface waves and normal modes, earthquake source theory, intensity and magnitude scales of earthquakes, PREM model, elastic rebound theory, global seismecity and tectonics, focal mechanisms, seismic anistropy; Heat within the Earth, thermal structure of continental and oceanic lithospheres at subduction zones and spreading centres, mantle convection. **Course Reference**: 1. Lowrie, W; Fundamentals of Geophysics, Cambridge University Press; 2. Fowler, C.M.R., 2004, The Solid Earth: An Introduction to Global Geophysics; Cambridge University Press; 3. Robert J. Lillie, 1999; Whole Earth Geophysics: An Introductory Textbook for Geologists and Geophysicists, Prentice Hall. 11-MAR-2016.
ES315A	IGNEOUS & METAMORPHIC PETROLOGY	3-0-2-0-11	This course will introduce igneous and metamorphic rocks and focus on the processes and principles involved in the generation of these rocks in a wide range of tectonic settings. Emphasis will be on developing skills necessary to understand and evaluate melt generation and crystallization, differentiation and chemical evolution of magma, and metamorphic processes etc. Topics to be discussed in detail are :

			Classification and Nomenclature of Igneous Rocks; Textures and Petrogenetic Interpretations; Thermodynamic evaluation of phase diagrams Phase Diagrams for Binary and Ternary Systems; Chemical Petrology: Major and minor element, and isotopic compositional variations; graphical and mathematical models of magme evolution; Fractionation of trace elements during melting and crystallization; Generation and diversification of magmas; Types of metamprphism; Classification of metamorphic rocks; textures; Metamorphic mineral assemblages and chemographic (ADF, AKF, and AFM) giagrams; Metamorphic Facies; Metamorphic Reactions. **Course Reference**: 1. An Introduction to Igneous and Metamorphic Petrology by John D. Winter (Prentice Hall, 2nd edition); 2. The Interpretation of Igneous Rocks by Cox, Bell and Pankhurst (Chapman and Hall); 3. Petrography of Igneous and Metamorphic Rocks by Philpotts (CBS, 1st edition, 2015) 11-MAR-2016.
ES411A	STRUCTURAL GEOLOGY	2-0-3-0-9	Concepts of deformation and structures in Earth and planetary systems; Concepts of Continuum, Solid, Fluid, Tensor, Force, Stress and Strain; Basics of rheology and deformation mechanisms; Structures associated with extensional, compressional, sliding tectonics and erosion; Fold morphology, kinematics and mechanism; Normal, reverse, oblique and strikeslip faults; Fold and thrust belts; Measurement and presentation of 1, 2 and 3D structural elements; Ductile shear zones; Polyphase (superposed) deformation and overpriting relationships; Application of Structural Geology. **Course Reference**: 1. Ramsay, J.G., & Huber, M.I., 1983. The Techniques of Modern Structure Geology: V.1: Strain analysis. NY, Academic Press, 307 p; 2. Ramsay, J.G., and Huber, M.I., 1987. The Techniques of Modern Structural Geology, V.2: Folds and Fractures, NY, Academic Press, 392 p; 3. Ramsay, J.G., and Lisle, R.J., The Techniques of Modern Structural Geology, V.3: Applications of Continuum Mechanics in Structural Geology. Academi Press, 361 p. 11-MAR-2016.
ES412A	SEDIMENTARY PROCESSES & STRATIGRAPHIC PRINCIPLES	2-0-2-0-8	Basinal Sedimentary Systems: Sedimentary basisn and production of sediments; Transport of sediment grains; depositional processes and forms; Post depositional changes lithification and diagenesis. Sediment grain, Bedforms and Sedimentary Structures: Mechanics of sediment transport and transport laws; Grain size parameters and distribution, grain shape and form; primary grain fabric; Bedforms & inorganic primary sedimentary structures. Sedimentary Facies

			analysis: Concept of sedimentary facies; facies relationships; controlling factors; facies association and models; Fluvial environments and facies; Lacustrine facies, Deltaic environments and facies models. Clay Sedimentology: Origin of clay minerals, clay minerals in fluvial, aeolian and lacustrine environments, paleoenvironmental interpretations. Techniques in elastic sedimentology: Grain size determination; Xray diffraction; Heavy mineral analysis; cathodoluminescence microscopy. **Course Reference**: 1. Allen P.A. and Allen J.R., Basin Analysis: Principles and Application, Blackwell publishing; 2. Leeder M., Sedimentology and Sedimentary Basin: from Turbulence to Tectonics; Wiley Blackwell; 3. Selley R.C., Applied Sedimentology; Academic Press; 4. Reading H.G., 2009, Sedimentary Environments: processes, facies and stratigraphy, Blackwell. 11-MAR-2016
ES413A	GEOCHEMISTRY	2-0-0-0-6	Internal structure of atoms, electronic structure, chemical bonding, and chemical properties of elements. Fundamentals of Thermodynamics and its application in Earth Sciences. Aquatic geochemistry, primary silicates and chemical weathering, acids and bases, dissolution and precipitation reactions, mineral stability diagrams, Eh pH diagrams, oxidation reduction reactions. The origin and evolution of Earth and the solar system through high temperature chemical processes, trace elements in igneous processes, modeling trace element partition during magma genesis. Radiogenic isotope geology and geochrolology. Stable isotope geochemistry. Earth's hydrosphere and its interaction with surficial rocks, sediments, soils, biosphere and the atmosphere. **Course Reference**: 1. Principles and applications for Geochemistry (1998). Faure, G., Prentice Hall ISBN 10:0023364505; 2. Geochemistry: Pathways and Processes (2004). McSween, H.Y., Richardson, S.M., Uhle, M., Columbia University Press ISBN 10:0231124406; 3. Geochemistry (2013). White, W., Wiley Blackwell ISBN 10:047656686. 11-MAR-2016
ES414A	FIELD GEOLOGY II	0-0-6-0-6	This course is designed to provide practical experience in stratigraphy including field logging of stratigraphic sections, sedimentary facies identification and description, interpretation of sedimentary processes, depositional environments, postdepositional changes; soil profiles and soil forming processes. The students will also be taught geophysical data acquisition using available geophysical equipments (e.g., gravimeter, magnetometer, VLF electromegnetic equipment, resistivitimeter equipment, GPR, Scismic, and

			Global positioning system). **Course Reference**: 1. Compton, R. (1985) Geology in the field, Wiley; 2. Lahee, F.H. (2002). Field geology, CBS publishers; 3. John Milson and Asger Eriksen, 2011, Field Geophysics (4th Edition): Wiley Blackwell; 4. Reynolds, J.M. (2011), An Introduction to Applied and Environmental Geophysics, Second Edition: Wiley; 5. Everett, M.E., 2013, Near surface applied geophysics: Cambridge University Press. 11-MAR-2016
ES415A	GEOLOGICAL REMOTE SENSING AND GIS	2-0-2-0-8	Spectra of earth's surface material; Basic principles of digital image processing point and algebric operations, filtering and neighbourhood processing, RGB HIS transformations, image fusion analysis, PCA, image classification and geometric operations; Modern platforms and techniques INSAR techniques and its applications, UAV, and airborne sensors. Basic principles of Geographic Information System (GIS) and its application decision support and uncertainty, multicriteria evaluation. Remote sensing applications River basin management, groundwater prospecting, lake and wetland studies, water quality mapping, vegetation Mapping and forestry applications; applications in glaciology and snow hydrology; snow cover mapping and prediction of snowmelt runoff; Coastal zone mapping and other related applications; Natural hazards floods, landslides, earthquakes; Mineral resources evalution. **Course Reference**: 1. Gupta, R.P. (1991), Remote Sensing Geology, Springer verlog; 2. Lio, J.G. an Mason, P. (2009). Essential image processing and GIS for remote sensing. Wiley Blackwell; 3. Lillesand, T.M. & Kiefer, R.W. (1994), Remote sensing and image interpretation, John Wiley & Sons; 4. Langley, P.A., Goodchild, M.F., Maguire, D.J. & Rhind. D.W. (1999), Geographical Information Systems, Vol. 1 & 2, John Wiley & Sons; 5. Carbonneau, P. and Piegay, H. (2012). Fluvial remote sensing for science and management. Wiley Blackwell. 11-MAR-2016
ES416A	EXPLORATION GEOPHYSICS	2-0-2-0-8	Introduction to exploration geophysics; Gravity and Magnetic methods: History of gravity magnetic explorations, elementary theories of gravity and magnetic methods, densities and magnetic susceptibilities of rocks and minerals, brief on gravimeters and magnetometers, data reductions, gravity magnetic anomalies, interpretation and applications; Electrical and electomagnetic methos: Electrical properties of rocks and minerals, self potentioal and its origin, concepts of D.C. resistivity, various electode configurations for sounding and profiling, interpretation of resistivity field data, induced polarization; Basic concept of

			EM induction, Maxwell's equations, different EM methods, earth's natural electromagnetic field, magneto tellurics, various applications of EM;Seismic methods: Basics of seismic theory, Geometry of seismic wave paths, seismic events, feflection and refraction methods, seismic data acquisition system, convolutional model, basic processing steps, basic velocity depth modeling, interpretation of seismic data. Radiometric methos: Principles of radioactivity, radioactivity of rocks and minerals, measuring instruments and applications; Well logging: Borehole environment, concepts of porosity, permeability and saturation, principles of electrical, nuclear, density and sonic logging and well log interpretation. **Course Reference**: 1. Telford, W.M., Geldart, L.P., and Sheriff, R.E., 1990, Applied geophysics (2nd Edition), Cambridge University Press; 2. Keary, P., Brooks, M., and Hill, I., 2002, An introduction to geophysical exploration (3rd edition), Balckwell Publishing; 3. Everett, M.E., 2013, Nearsurface applied geopysics, Cambridge University Press; 4. Serra, O., 1987, Fundamentals of Welllog Interpretation, Elsevier; 5. Sheriff, R.E., and Geldart, L.P., 1995, Exploration Seismology, Cambridge University Press. 11-MAR-2016
ES417A	GEOLOGICAL EVOLUTION OF INDIAN PLATE	2-0-0-0-6	Overview of geologic and tectonic evolution of the Indian plate, major geologic and tectonic features of the Indian subcontinent, Geodynamics and major structural grains in the Indian subcontinent; Indian Mountain buildings in geological time and space; Cratons (Dharwar, Singbhum, Bastar, Bundelkhand, Aravalli etc.) and their development in the Archean; Proterozoic basins (Chhatisgarh, Cuddapath, Marwar, Pranhita Godavari and Vindhyan), Gondwana basin; Rifting, drifting, Palaeomagnetic interpretation and the evolution of India's continental margins; The concept of Large Indian Provinces in global context; Rajmahal and Deccan volcanic provinces; Plateau uplift (Deccan, Tibet and Shillong); Phanerozoic stratigraphic records of pennsular India; The Himalaya mountains; northward flight of India and collisional orogenesis; Classification of the Himalayan ranges; Himalayan foreland development and IndusGangaBrahmaputra plains. **Course Reference**: 1. Ramakrishnan, M. and Vaidyanadhan, R., 2008. Geology of India: Vol: I and II, Geological Society of India Publication; 2. Wadia, D.N. 1919. Geology of India for students, McMillan and Co., Ltd. 466 p; 3. Valdiya, K.S., 2015. The Making of India Geodynamics Evolution, 2nd Edition (Society of Earth Scientist Series), Springer, 942 p. 11-MAR-2016

ES418A	FIELD GEOLOGY III	0-0-4-0-4	General overview of geological structures in the field; Concept of orientation and scale in the field; Identification, measurement and presentation of different structural elements (lineation, cleavage, foliation, schistocity etc.) and their mutual relationships. Morphology and elements of fold, fractures, faults, shear zones and macrostructures; Strain analysis from deformed objects; Technique and ethics of geological samples collection; Large and small scale lithostructural mapping (on toposheet and white paper), crosssections, and their interpretation for regional tectonics. **Course Reference**: 1. Davis, G.H., & Reynolds, S.J., 1996. Structural Geology of rocks and Regions (2nd Ed): NY, John Wiley & sons, 776 p; 2. Lisle, R.J., 1995. Geological Structures & Maps, a Practical Guide. 2nd Ed., Butterworth / Heinmann, Woburn, 104 p; 3. Bennison, G.M., and K.A., Moseley, 1998. Geologic Structures & Maps; 6th edition. Arnold, London, 129 p. 11-MAR-2016
ES640	EARTH SYSTEM PROCESSES	3-0-0-4-4	Principles: Earth System processes, geomorphic systems, Threshold and equilibrium; scale in geomorphology, key concepts in geomorphology, hydrologic cycle. Processes and Products: Exogenetic and endogenetic processes, climatic vs. geomorphic processes, soil and weathering system. The Surface water system: Drainage basins and river systems, river morphology and hydrology, fluvial erosion, transport and sedimentation, fluvial depositional landforms, geomorphometric concepts and drainage basin morphometry. The Groundwater system: Groundwater in hydrological cycle, water table, groundwater flow and storage; porosity and permeability, aquifers, chemistry of groundwater. The Atmospheric System: Atmospheric composition and mixing, atmospheric circulation, greenhouse effect. The Ocean and Coastal system: Coastal environment, waves, tides and currents, description and classification of coasts, shoreline development, coastal erosion and resulting topographic features, coastal deposition and landforms. Global geomorphology and tectonics: Earths physiography and landscape evolution; Landforms and tectonics of plate margins and plate interiors; Tectonic uplifts and denudation rates and controlling factors, Sea level change evidence, mechanism and effects; coupled tectonicsurface process models. **Course Reference**: 1.Summerfield, S.A. (1991) Global Geomorphology, Longman; 2.Ernst, W.G. (2000) Earth Systems: Processes and Issues, Cambridge University Press; 3.Richards, K.S. (1982) Rivers forms and processes in alluvial

			channels, Metheun; 4.Kale, V. and Gupta, A. (2001) Introduction to Geomorphology, Orient Longman; 5.Thronbury, W.D. (1969) Principles of geomorphology, John Wiley & Sons; 6.Williams, M.J. (1998) Quaternary Environments, Arnold Publishers; 7.Reading, H.G. (1996) Sedimentary Environments. Blackwell; 8. Merrits, D, Dewet, A. and Menking, K. (1998) Environmental Geology: An earth system science approach. W.H. Freeman.
ES640A	EARTH SYSTEM PROCESSES	3-0-0-0-9	Principles: Earth System processes, geomorphic systems, Threshold and equilibrium; scale in geomorphology, key concepts in geomorphology, hydrologic cycle. Processes and Products: Exogenetic and endogenetic processes, climatic vs. geomorphic processes, soil and weathering system. The Surface water system: Drainage basins and river systems, river morphology and hydrology, fluvial erosion, transport and sedimentation, fluvial depositional landforms, geomorphometric concepts and drainage basin morphometry. The Groundwater system: Groundwater in hydrological cycle, water table, groundwater flow and storage; porosity and permeability, aquifers, chemistry of groundwater. The Atmospheric System: Atmospheric composition and mixing, atmospheric circulation, greenhouse effect.The Ocean and Coastal system: Coastal environment, waves, tides and currents, description and classification of coasts, shoreline development, coastal erosion and resulting topographic features, coastal deposition and landforms.Global geomorphology and tectonics: Earths physiography and landscape evolution; Landforms and tectonics of plate margins and plate interiors; Tectonic uplifts and denudation rates and controlling factors, Sea level change evidence, mechanism and effects; coupled tectonicsurface process models. **Course Reference**: 1.Summerfield, S.A. (1991) Global Geomorphology, Longman; 2.Ernst, W.G. (2000) Earth Systems: Processes and Issues, Cambridge University Press; 3.Richards, K.S. (1982) Rivers forms and processes in alluvial channels, Metheun; 4.Kale, V. and Gupta, A. (2001) Introduction to Geomorphology, Orient Longman; 5.Thronbury, W.D. (1969) Principles of geomorphology, John Wiley & Sons; 6.Williams, M.J. (1998) Quaternary Environments, Arnold Publishers; 7.Reading, H.G. (1996) Sedimentary Environments. Blackwell; 8. Merrits, D, Dewet, A. and Menking, K. (1998) Environmental Geology: An earth system science approach. W.H. Freeman.
ES642	GEOCHEMISTRY	3-0-0-0-4	Course outline, grading policy, introduction to geochemical cycles, periodic table, Origin of the

			universe and Earth, Earths history from its creation to Anthropocene, The Basics: Nuclear (in) stability, isotopes, particles, modes of radioactive decay, chart of nuclides, nucleosynthesis, Nucleosynthesis continued, Thermodynamics, Radioactive decay, principles of geochronology and isochrons, radiogenic isotopes as geochronometer and process tracers, mixing and modeling calculations, RbSr, SmNd, UThPb and ReOs systematics, Cosmogenic radionuclides: 1. 4C, 10Be, 26Al theory, models and applications, Discussion on assignments, 2 & 3, as well as reading material, Fractionation of stable isotopes, H, O, C, Discussion on assignment, 4 and reading material, Mass spectrometry: Measurement principles and methodology, techniques such as isotope dilution. **Course Reference**: 1. Principles and Applications of Geochemistry by Gunter Faure (2nd edition, Prentice Hall) Geochemistry: pathways and Processes by McSween, Richardson, Uhle (Columbia University Press); 2. Geochemistry an Introduction by F. Albarede (Cambridge University Press) Introduction to Geochemistry by Krauskopf and Bird (McGrawHill)
ES642A	GEOCHEMISTRY	3-0-0-0-9	Course outline, grading policy, introduction to geochemical cycles, periodic table, Origin of the universe and Earth, Earths history from its creation to Anthropocene, The Basics: Nuclear (in) stability, isotopes, particles, modes of radioactive decay, chart of nuclides, nucleosynthesis, Nucleosynthesis continued, Thermodynamics, Radioactive decay, principles of geochronology and isochrons, radiogenic isotopes as geochronometer and process tracers, mixing and modeling calculations, RbSr, SmNd, UThPb and ReOs systematics, Cosmogenic radionuclides: 1. 4C, 10Be, 26Al theory, models and applications, Discussion on assignments; 2 & 3, as well as reading material, Fractionation of stable isotopes, H, O, C, Discussion on assignment; 4 and reading material, Mass spectrometry: Measurement principles and methodology, techniques such as isotope dilution. **Course Reference**: 1. Principles and Applications of Geochemistry by Gunter Faure (2nd edition, Prentice Hall) Geochemistry: pathways and Processes by McSween, Richardson, Uhle (Columbia University Press); 2. Geochemistry an Introduction by F. Albarede (Cambridge University Press) Introduction to Geochemistry by Krauskopf and Bird (McGrawHill)
ES644A	REMOTE SENSING AND GIS FOR GEO-		Remote sensing platforms satellite based and airborne sensors; Basic principles of image

	RESOURCE EVALUATION COURSE		interpretation; Spectra of earths surface material; Interpretation of regional geological and geomorphological features; Lithological and structural mapping, mapping of landforms and interpretation; Basic principles of geographic Information System (GIS) and its application; Analytical Hierarchy Process (AHP) technique and its integration into GIS. River erosion studies; Identification of groundwater potential zones; criteria for identification, integration of controlling factors into GIS; Lake and wetland studies using remote sensing; Water quality mapping; water quality parameters,indices of water quality monitoring; Vegetation Mapping and forestory applications; Application in glaciology and snow hydrology; Coastal zone mapping and other related applications; Natural hazardsfloods, landslides,earthquakes; causative factors, choice of data and use of remote sensing technique for mapping and prediction; Mineral resources evaluation with particular reference to digital remote sensing; Application of thermal infrared data for mapping surface moisture and rock types and environmental studies.
ES646	GLOBAL CLIMATE CHANGE	3-0-0-4-4	Introduction to global climate: earths climate system, time scales of climate change, climate forcings and response systems, climate feedbacks and interactions. Earths radiation budget and circulation systems: Earths tilt and seasonal radiation, hydrological cycle, atmospheric circulation, monsoonal circulation, ocean circulation, oceanic conveyor belt. Climate archives and proxies: Methods of reconstructing climate, Ice sheet, sedimentary archives, biotic proxies, geological and geochemical proxies. Global climatic models: 1D, 2D and 3D atmospheric models, Global Circulation Models (GCMs), Ice sheet model, vegetation feedback, geochemical models Quaternary climates: Sea level changes, glacial/interglacial cycles, tectonics climate coupling, sea floor spreading, BLAG hypothesis, Uplift weathering hypothesis, carbon reservoir, vegetation dynamics, migration history, response of vegetation to climatic reversals Geological records of climate change: Sedimentology, stable isotopes, geochemistry, geochronology relative and numerical methods, PreQuaternary climates, evolution of climate through geological time.Impacts of climate change: impacts on water resources rivers, oceans, lakes, ecological systems, socioeconomic impacts, mitigation strategies. **Course Reference**: 1. Ruddiman, W.F. 2001. Earths Climate: past and Future. W.H. Freeman &

			Co; 2. Bradley, R. S., 1999, Quaternary paleo climatology; 3. Williams, M., Dunkereley, D., Decker, P.D., Kershaw, P. & Chappel, J. (1998) Quaternary Environments; 4. Burroughs, W.J. (2001) Climate Change: A multidisplinary Approach; 5. Merrits, D., Dewet, A. and Menking, K., (1998) Environmental geology; an earth system science approach, Freeman.
ES646A	GLOBAL CLIMATE CHANGE	3-0-0-0-9	Introduction to global climate: earths climate system, time scales of climate change, climate forcings and response systems, climate feedbacks and interactions. Earth's radiation budget and circulation systems: Earths tilt and seasonal radiation, hydrological cycle, atmospheric circulation, monsoonal circulation, ocean circulation, oceanic conveyor belt. Climate archives and proxies: Methods of reconstructing climate, Ice sheet, sedimentary archives, biotic proxies, geological and geochemical proxies.Global climatic models: 1D, 2D and 3D atmospheric models, Global Circulation Models (GCMs), Ice sheet model, vegetation feedback, geochemical models Quaternary climates: Sea level changes, glacial/interglacial cycles, tectonics climate coupling, sea floor spreading, BLAG hypothesis, Upliftweathering hypothesis, carbon reservoir, vegetation dynamics, migration history, response of vegetation to climatic reversals Geological records of climate change: Sedimentology, stable isotopes, geochemistry, geochronology relative and numerical methods, PreQuaternary climates, evolution of climate through geological time.Impacts of climate change: impacts on water resources rivers, oceans, lakes, ecological systems, socioeconomic impacts, mitigation strategies. **Course Reference**: 1. Ruddiman, W.F. 2001. Earths Climate: past and Future. W.H. Freeman & Co; 2. Bradley, R. S., 1999, Quaternary paleoclimatology; 3 Williams, M., Dunkereley, D., Decker, P.D., Kershaw, P. & Chappel, J. (1998) Quaternary Environments; 4. Burroughs, W.J. (2001) Climate Change: A multidisplinary Approach; 5. Merrits, D., Dewet, A. and Menking, K., (1998) Environmental geology; an earth system science approach, Freeman.
ES647	PETROLEUM EXPLORATION AND PRODUCTION		
ES652	IGNEOUS AND METAMORPHIC PETROLOGY	3-0-0-4-4	This course will focus on the processes and principles involved in the generation of Earth materials, in particular, igneous and metamorphic rocks. Students will gain a broad overview of the Earth as dynamic system that produces a variety of

			igneous and metamorphic rocks in a wide range of tectonic settings with emphasis on developing skills necessary to understand and evaluate melt generation and crystallization, differentiation and chemical evolution of magma, and metamorphic processes etc. Topics to be discussed in detail are:Classification and Nomenclature of Igneous Rocks; Textures and Petrogenetic Interpretations; Thermodynamic evaluation of phase diagrams; Phase Rule and One Component System; Phase Diagrams for Binary Systems (Solid solution, Eutectic, and Peritectic systems) such as Forsterite Fayalite, Albite Anorthite, DiopsideAnorthite, OrthoclaseAlbite, and Forsteritesilica; Three component Systems (Anorthite Diopside Forsterite, and Anorthite Forsteritesilica); Effect of P, T & fluids on Melting; Chemical Petrology: Major and minor element, and isotopic compositional variations; graphical and mathematical models of magma evolution; Fractionation of trace elements during melting and crystallization; Rare Earth Element (REE) patterns and modeling source magma composition; Generation and diversification of magmas; MidOcean Ridge Volcanism; Mantle Plumes and Ocean Island Basalts; Subduction related Arc magma generation; Types of metamorphism; Classification of metamorphic rocks; textures; Metamorphic mineral assemblagesband chemographic (ACF, AKF, and AFM) diagrams; Metamorphic Facies; Metamorphic Reactions. Text: An Introduction to Igneous and Metamorphic Petrology by John D. Winter (Prentice Hall, 2nd edition) Recommended readings: **Course Reference**: 1. The Interpretation of Igneous Rocks by Cox, Bell and Pankhurst (Chapman and Hall); 2. Principles of Igneous and Metamorphic Petrology by Anthony Philpotts and Jay Ague (Cambridge University Press; 2nd edition); 3. Petrology: Igneous, Sedimentary and Metamorphic by Blatt, Tracy, and Owens (Freeman and Company)
ES652A	IGNEOUS AND METAMORPHIC PETROLOGY	3-0-0-0-9	This course will focus on the processes and principles involved in the generation of Earth materials, in particular, igneous and metamorphic rocks. Students will gain a broad overview of the Earth as dynamic system that produces a variety of igneous and metamorphic rocks in a wide range of tectonic settings with emphasis on developing skills necessary to understand and evaluate melt generation and crystallization, differentiation and chemical evolution of magma, and metamorphic processes etc. Topics to be discussed in detail are:Classification and Nomenclature of Igneous

			Rocks; Textures and Petrogenetic Interpretations; Thermodynamic evaluation of phase diagrams; Phase Rule and One Component System; Phase Diagrams for Binary Systems (Solid solution, Eutectic, and Peritectic systems) such as Forsterite Fayalite, Albite Anorthite, Diopside Anorthite, Orthoclase Albite, and Forsterite silica; Three component Systems (Anorthite Diopside Forsterite, and Anorthite Forsteritesilica); Effect of P, T & fluids on Melting; Chemical Petrology: Major and minor element, and isotopic compositional variations; graphical and mathematical models of magma evolution; Fractionation of trace elements during melting and crystallization; Rare Earth Element (REE) patterns and modeling source magma composition; Generation and diversification of magmas; MidOcean Ridge Volcanism; Mantle Plumes and Ocean Island Basalts; Subduction related Arc magma generation; Types of metamorphism; Classification of metamorphic rocks; textures; Metamorphic mineral assemblages and chemographic (ACF, AKF, and AFM) diagrams; Metamorphic Facies; Metamorphic Reactions. **Course Reference**: 1. An Introduction to Igneous and Metamorphic Petrology by John D. Winter (Prentice Hall, 2nd edition) Recommended readings:1. The Interpretation of Igneous Rocks by Cox, Bell and Pankhurst (Chapman and Hall); 2. Principles of Igneous and Metamorphic Petrology by Anthony Philpotts and Jay Ague (Cambridge University Press; 2nd edition); 3. Petrology: Igneous, Sedimentary and Metamorphic by Blatt, Tracy, and Owens (Freeman and Company)
ES659A	ACTIVE TECTONICS AND PALEOSEISMOLOGY	3-0-0-0-9	Crustal deformation and earthquakes (02); significance of seismicity (01); Identification of Prehistoric Earthquakes based on Primary and Secondary signatures preserved in landforms and sediment succession (03); Interpretation and Identification of Active Fault and associated Tectonic Landforms Photogeologic Mapping, onfault and offfault landforms, indentification and mapping of active faults and associated landforms in field, structural analysis of active faults & its implication to regional scale tectonics (04); Field Techniques in Paleoseismology, quantification of active fault scarp by precise mapping, identification of old (prehistoric) earthquake by trenching, mapping of deformed sedimentary succession by faulting, estimation of net displacement during single event, slip rate, magnitude of historic earthquake, recurrene interval, and prediction of future earthquake if possible (05); Identification and mapping of secondary effects due to strong

			seismic shaking identification of paleoliquefaction features (02); Dating techniques (01); Correlation of paleoseismic data with existing geodetic and geophysical data (01); Delineation of seismogenic faults (01).Paleotsunami geology Identification of Paleotsunami and Megasubduction zone earthquakes signatures in the coastal region along subduction zones (05); Understanding landlevel change caused by major earthquakes (02); decoupling the role of climate and tectonics (01); Understanding the effect of nearfield and farfield earthquakes from stratigraphic records (01); effects of near field and farfield tsunami (01). **Course Reference**: 1. McCalpin, J.P., (1996), Paleoseismology, Academic Press, New York, p. 588; 2. Yeats, R.S., Sieh, K., Allen, C.R., (19997), Geology of Earthquakes, Oxford Univ. Press, 568; 3. Shiki, T., Tsuji, Y., Yamasaki, T., Minoura, K. Tsunamiites, Elsevier, Amsterdam; 4. Burbank, D. W. and Anderson, R.S. Tectonic Geomorphology, Blakwell Sciences, 287; 5. Bull, W. B. Tectonic Geomorphology of Mountains; A new Approach of Paleoseismology, Blackwell Sciences, 326.
ES699	M TECH THESIS	----	M. Tech. Thesis
ES799	PH D THESIS	----	Ph. D. Thesis
ESO213A	FUNDAMENTALS OF EARTH SCIENCES	3-0-0-0-9	universe and its characteristics Solar System and Earth The primitive Earth Geological Time scale Origin of the life and major geological events Numerical Dating. Rocks, minerals and soils; Plate Tectonics and Mountain building, Deformation and Geodynamics Earthquakes; Volcanoes.Earth, Ocean, Land, Rivers, Atmosphere, Biosphere, Cryosphere and Climate; Energy budget; Carbon Cycle; Hydrological Cycle; Weathering and erosion. coupled processoes in Earth System; climate change, Geological resourses (minerals, hydrocarbons and water); Sustainability and Anthropocene activities **Course Reference**: 1. D.R. Prothero and R.H. Dott, Jr. Evolution of the Earth. 2010 (8th Ed.), McGraw Hill, 576p; 2. E.J. Tarbuck, F.K. Lutgens and D.G. Tasa. Earth: An introduction to Physical Geology, 2013 (11th Ed.). Prentice Hall. 912 p; 3. J. Grotzinger and T. Jordan, Understanding Earth, 2010 (6th Ed.). Freeman, 210p.

HUMANITIES AND SOCIAL SCIENCE

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DEPARTMENT OF HSS			
CourseID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
ART101A	INDIAN ART AND CIVILIZATION	3-1-0-0-11	Indian Art from Ancient Times: Rock Paintings of Bhimbetka and Indus Valley Civilization;Early Indian Art (1st and 10th Century A.D.): Buddhist Art from Gandhara and Kushan School,Buddhist Arts of Samath, Ajanta and Ellora, Chalukyan Art of Badami, Rashrakuta Art of Deccan; Medieval Indian Art (10th and 14th Century A.D.): Chola Art of Deccan Temples of Khajuraho, Temple of Konark, Paintings of Lepakshi; 15th to 19th Century Art: MoghulMiniatures, Jain Miniature, Mysore and Tanjore Schools of Art, Guier and Kulu MiniaturesRajasthani and Pahari Schools, Company and Bazar Art; Contemporary and Modem Indian Art 20th and 21st Century: Individual Artists. **Course Reference**: 1. Indian Art A Concise History by Roy C. Craven; 2. Early India From the Origins to AD 1300 by Romila Thapar; 3. Moving Focus: Essays on Indian Art by K.G. Subramanyan; 4. TheMaking of a New-Indian-Art by Tapati Guha Thakurta; 5. Indian Art (Oxford History of Art) by Partha Mitter; 6. Faces of Indian Art Edited by Ina Puri
ART102	INTRODUCTION TO ART CRITICISM AND APPRECIATION	3-0-1--4	What is Art, What is art appreciation, History of Art Criticism, Methodology of Critical Art Appreciation, Elements and Principles of Visual Art, Characteristics of art of Prehistoric,Ancient, middle age, Dark Age, modem, post modem era in context of world art (Western,Indian, Oriental and Far Eastern Art), Introduction to methods and materials.Practice: Still life, Nature Study, Composition, Symmetry, Narrative Continuity, 2D and 3D Exercises Jaoson's Basic History of Western Art by Penelope CaviesArt of Twentieth Century by Loredana ParmesaoiIndiao Art. **Course Reference**: 1. A Concise History by Roy C. Craven Early India From the Origins to AD 1300 by Romila Thapar. The Story of Art E.H. Gombrich; 2. Design Basics by David A, Lauer, Holt, Rinehart and Winston Book on Far Eastern Art (Chinese aod Japaoese Art) Skira; 3. Sharman Lee Publishers Moving Focus: Essays on Indian Art by K.G.

			Subramaoyao; 4. The Making of a New, Indiao; Art by Tapati Guha Thakurta Indiao Art (Oxford History of Art) by Partha MitterFaces ofindiao Art Edited by Ina Puri
ART102.	INTRODUCTION TO ART CRITICISM AND APPRECIATION	3-0-1-0-4	What is Art, What is art appreciation, History of Art Criticism, Methodology of Critical Art Appreciation, Elements and Principles of Visual Art, Characteristics of art of Prehistoric,Ancient, middle age, Dark Age, modem, post modem era in context of world art (Western,Indian, Oriental and Far Eastern Art), Introduction to methods and materials.Practice: Still life, Nature Study, Composition, Symmetry, Narrative Continuity, 2D and 3D Exercises Jaoson's Basic History of Western Art by Penelope Cavies Art of Twentieth Century by Loredana ParmesaoiIndiao. **Course Reference**: 1. Art A Concise History by Roy C. Craven Early India From the Origins to AD 1300 by Romila ThaparThe Story of Art E.H. Gombrich; 2. Design Basics by David A, Lauer, Holt, Rinehart aod WinstonBook on Far Eastern Art (Chinese aod Japaoese Art) Skira, Sharman Lee Publishers: Moving Focus: Essays on Indian Art by K.G. Subramaoyao; 4. The Making of a New, Indiao; Art by Tapati Guha ThakurtaIndiao. Art (Oxford History of Art) by Partha MitterFaces ofindiao Art Edited by Ina Puri
ART102A	INTRODUCTION TO ART APRECIATION & CRITICISM	3-1-0-0-11	Introduce fundamental visual skills and analytical skills, Critical thinking about various forms of art, and close observation of art and performing art.Principles of Analysis of Art, Art and perception, What is Style?, Style in Painting,Colour, Psychology of Colour Perception & Design, Space Illusion, Painting,Sculpture, Style in Sculpture Architecture, Style in Architecture, Space in Architecture, Printmaking, Photography & Film, POP Art Comics, Advertisements etc, Performing Art, Methodology of Criticism & Appreciation.Studio: 2D Exercise, Printmaking, 3D Exercises, Sculpture, Field Trip.
ART103	INTRODUCTION TO WESTERN ART	3-1-0-0-4	What is Art? Cave Paintings: 14,00010,000 BC: Altamira Cave Paintings; The Art of theClassical Civilizations: 3,000 BCAD 500: 8000600 BC: Mesopotamia; 3000270 BC: Egypt;1230100 BC: Greece; 700 BCAD 325: Rome; 3251453: Byzantium; The Art of the MiddleAges: 4751500: 4751000: The Dark Ages; 10001350: The High Middle Ages; 13501500: TheLate Middle Ages; The Art of the Modern Period: 1500present: 14001550: Renaissance;15501700: Baroque; 17001800: Rococo and Classical; 17901850: Romantic; 18501910: Realism, Impressionism, Expressionism; 19101950: Cubism, Fauvism, Abstraction, Modernism, Dada; 1950present: Recent Janson's Basic History of Western Art by Penelope CaviesArt of Twentieth Century by Loredana ParmesaniIndian Art.

			Course Reference: 1. A Concise History by Roy C. Craven Early India From the Origins to AD 1300 by Romila Thapar; 2. The Story of Art E.H.Gombrich; 3. Design Basics by David A, Lauer, Holt, Rinehart and Winston Book on Far Eastern Art (Chinese and Japanese Art) Skira, Sharman Lee Publishers Moving Focus: Essays on Indian Art by K.G. Subramanyan; 4.The Making of a New, Indian Art by Tapati Guha Thakurta Indian Art (Oxford History of Art) by Partha Mitter Faces of Indian Art Edited by Ina Puri
ART103A	INTRODUCTION TO WESTERN ART	3-1-0-0-11	What is Art? Cave Paintings: 14,00010,000 BC: Altamira Cave Paintings; The Art of the Classical Civilizations: 3,000 BCAD 500: 8000600 BC: Mesopotamia; 3000270 BC: Egypt;1230100 BC: Greece; 700 BCAD 325: Rome; 3251453: Byzantium; The Art ofthe Middle Ages: 4751500: 4751000: The Dark Ages; 10001350: The High Middle Ages; 13501500: The Late Middle Ages; The Art of the Modern Period: 1500present: 14001550: Renaissance;15501700: Baroque; 17001800: Rococo and Classical; 17901850: Romantic; 18501910: Realism, Impressionism, Expressionism; 19101950: Cubism, Fauvism, Abstraction, Modernism, Dada; 1950present: Recent Janson's Basic History of Western Art by Penelope CaviesArt of Twentieth Century by Loredana Parmesani Indian Art A Concise History by Roy C. **Course Reference**: 1. Craven Early India From the Origins to AD 1300 by Romila ThaparThe Story of Art E.H. Gombrich; 2. Design Basics by David A, Lauer, Holt, Rinehart and Winston Book on Far Eastern Art (Chinese and Japanese Art) Skira, Sharman Lee PublishersMoving Focus: Essays on Indian Art by K.G. Subramanyan; 3. The Making of a New, Indian; Art by Tapati Guha Thakurta Indian Art (Oxford History of Art) by Partha MitterFaces ofIndian Art Edited by Ina Puri
ART104A	ARCHITECTURE AND ENVIRONMENTAL DESIGN	3-1-0-0-11	Manmade Environment and Natural Environment Primary Function of Enclosed Space shelter building, material consideration, Introduction to Architecture whatis architecture, difference between building and architecture.
ART105	INTRODUCTION TO THE ART OF VIDEO MAKING	3-0-1-0-4	Theory Cinematography, Production Process, Writing for Screen, Basics Picture Making, Camera Angles, Direction Time and Space continuity, Cuts, Art of Editing The 5C's of Cinematography, Mascelli Directing the Documentary, Michail Rabiger **Course Reference**: 1. A History of the Cinema, Eric Rhode. Writing for Screen and Television, Tobias Single camera video production; 2. Robert b. Musburger. Another Cinema for Another Society, Gaston Roberge Brand Bollywood, Bose Producing and Directing the Short Film & Video, Irving & Rea; 3. The Art of Cinema, B.D. Garga A compauion to Film

			Theory, Miller & Starn
ART105.	INTRODUCTION TO THE ART OF VIDEO MAKING	3-0-1-0-4	Theory Cinematography, Production Process, Writing for Screen, Basics Picture Making, CameraAngles, Direction Time and Space continuity, Cuts, Art of Editing The 5C's of Cinematography, Mascelli Directing the Documentary, Michail Rabiger **Course Reference**:1. A History ofthe Cinema, Eric Rhode Writing for Screen and Television, Tobias Single camera video production; 2. Robert b. Musburger Another Cinema for Another Society, Gaston Roberge Brand Bollywood, Bose Producing and Directing the Short Film & Video, Irving & Rea; 3. The Art of Cinema, B.D. Garga A compauion to Film Theory, Miller & Starn
ART105A	INTRODUCTION TO THE ART OF VIDEO MAKING	3-0-2-0-11	Theory Cinematography, Production Process, Writing for Screen, Basics Picture Making, CameraAngles, Direction Time and Space continuity, Cuts, Art of Editing The 5C's of Cinematography, Mascelli Directing the Documentary, Michail Rabiger. **Course Reference**: 1. A History ofthe Cinema, Eric RhodeWriting for Screen and Television, Tobias Single camera video production; 2. Robert b. MusburgerAnother Cinema for Another Society, Gaston Roberge Brand Bollywood, Bose Producing and Directing the Short Film & Video, Irving & Rea. 3.The Art of Cinema, B.D. Garga A compauion to Film Theory, Miller & Starn
ART106	ELEMENTS OF VISUAL REPRESENTATION	3-0-0-0-9	1. Space Two dimensional Spaces Illusion of Space One, two and multiple point perspective Three dimensional Spaces Space distribution Negative and Positive Space Object and ground relationship: Fore ground, middle ground, back ground Interactive Space; 2. Scale Natural space and natural scale Ideal space and ideal scale Scale Confusion in surreal space; 3. Illusion of motion Illusion of motion Anticipated and optical movement; 4. Line Line quality Line and Shape delineation; 5. Style of Visual Representation Form and Content Realistic, Semi abstract, Abstract, Typographic, Decorative Style What is Art? 6. Visual Harmony Unity Emphasis Balance Rhythm 7. Visual Perception Compositional Arrangement Gestalt Principle of universal whole; 8. Shape and Volume Naturalism and distortion Naturalism and Idealism Abstract Expression Form and Pattern Rectilinear and Curvilinear Pattern; 9. Tone and Texture Tactile and Visual texture Trompeloeil; 10. Colour Colour and Value Colour theory Colour Combination Hue and Saturation Colour Characteristics Cognitive perception Optical Colour Mixing; 11. Visual Culture Cultural Identity through Visual Interface Refinement of Expression Culture Specific Expressions Traditional and Contemporary Expression Tribal and Folk art Comic

			Art Applied and Commercial Art; 12. Medium of Representation (Method and Material). Process of Visual Communication (Thinking, looking and doing); 13.Visual Analysis (Conclusion) Evaluation Assignments, resentations, Examinations Varieties of Visual Experience Art as image and idea Vol.6 Edmund Burke Feldman Janson, H. W. History of ArtNew York: PrenticeHall and HarryN.Abrams, Inc 1977 De LucioMeyer, J. Visual Aesthetics,New York: Harper & Row 1974 Design Basics,Second Edition David A. Lauer, Holt, Rinehart and WinstonRudolf Arnheim,Art and Visual Perception, A Psychology of the Creative Eye, California E. H. Gombrich, Art and IllusionA study in the psychology of pictorial representation.The A. W. Mellon lectures in the fine arts, 1956 Bollingen series XXXV: 5 Princeton University Press, Princeton and Oxford Lorendana Permesani, Art of the Twentieth Century, Movements, Theories, Schools and Tendencies 19002000, SKIRA
ART106A	ELEMENTS OF VISUAL REPRESENTATION	3-1-0-0-11	1. Space Two dimensional Spaces Illusion of Space One, two and multiple point perspective Three dimensional Spaces Space distribution Negative and Positive Space Object and ground relationship: Fore ground, middle ground, back ground Interactive Space; 2. Scale Natural space and natural scale Ideal space and ideal scale Scale Confusion in surreal space; 3. Illusion of motion Illusion of motion Anticipated and optical movement; 4. Line Line quality Line and Shape delineation; 5. Style of Visual Representation Form and Content Realistic, Semi abstract, Abstract, Typographic, Decorative Style What is Art? 6. Visual Harmony Unity Emphasis Balance Rhythm; 7. Visual Perception Compositional Arrangement Gestalt Principle of universal whole; 8. Shape and Volume Naturalism and distortion Naturalism and Idealism Abstract Expression Form and Pattern Rectilinear and Curvilinear Pattern; 9. Tone and Texture Tactile and Visual texture Trompeloeil; 10. Colour Colour and Value Colour theory Colour Combination Hue and Saturation Colour Characteristics Cognitive perception Optical Colour Mixing; 11. Visual Culture Cultural Identity through Visual Interface Refinement of Expression Culture Specific Expressions Traditional and Contemporary Expression Tribal and Folk art Comic Art Applied and Commercial Art; 12. Medium of Representation (Method and Material)Process of Visual Communication (Thinking, looking and doing); 13. Visual Analysis (Conclusion) Evaluation Assignments, Presentations, Examinations Varieties of Visual Experience Art as image and idea Vol.6 Edmund Burke Feldman Janson, H. W. History of ArtNew York: PrenticeHall and HarryN.Abrams, Inc 1977De LucioMeyer, J. Visual Aesthetics,New York:

			Harper & Row 1974 Design Basics, Second Edition David A. Lauer, Holt, Rinehart and Winston Rudolf Arnheim, Art and Visual Perception, A Psychology of the Creative Eye, California E. H. Gombrich, Art and IllusionA study in the psychology of pictorial representation. The A. W. Mellon lectures in the fine arts, 1956; Bollingen series XXXV: 5 Princeton University Press, Princeton and Oxford Lorendana Permesani, Art of the Twentieth Century, Movements, Theories, Schools and Tendencies 19002000, SKIRA
ART401	APPRECIATING FAR-EASTERN CINEMA	3-0-0-0-4	This is a (theoretical) cinema study course, which presents a survey of the FarEastern films both as an art form for creative expression and as a medium of mass communication. The coursewill broadly orient students to the theoretical fundamentals of the cinema studies. The course will explore five major movie making countries of the FarEast Japan, Korea, Mainland China, HongKong and Taiwan. The films included in this course, span the decades between the post SecondWorld War era to the 21st century and they are mostly art house cinemas and are distinct in respect to their timeperiod, film makers, country language and genre. The course content comprises of vast level of theoretical and textual study. Berggreen, ShuLing Chen, and Rob Peaslee; Trans Chinese imagination: film and cross Strait perception as a historical case study for contextual journalism education; Asia Pacific Media Educator. Issue No.18. (Dec.2007): 155 170.Dai, Jinhua.; Hou HsiaoHsiens films: pursuing and escaping history; InterAsia Cultural Studies. Volume 9. Number 2 (2008): 239 250.Fang, Karen; Arresting Cinema: Surveillance and the City State in the Representation of Hong Kong; New Formations. 44.2 (2001): 12850. 17-SEP-14
ART401A	APPRECIATING FAR-EASTERN CINEMA	3-0-0-0-9	This is a (theoretical) cinemastudy course, which presents a survey of the Far Eastern films both as an art form for creative expression and as a medium of mass communication. The course will broadly orient students to the theoretical fundamentals of the cinema studies. The course will explore five major movie making countries of the Far East Japan, Korea, Mainland China, HongKong and Taiwan. The films included in this course, span the decades between the post Second World War era to the 21st century and they are mostly art house cinemas and are distinct in respect to their timeperiod, filmmakers, country language and genre. The course content comprises of vast level of theoretical and textual study. Berggreen, ShuLing Chen, and Rob Peaslee; Trans Chinese imagination: film and cross Strait perception as a historical case study for contextual journalism education; Asia Pacific Media Educator. Issue No.18. (Dec.2007): 155 170.Dai, Jinhua.; Hou

			Hsiao Hsiens films: pursuing and escaping history; InterAsia Cultural Studies. Volume 9. Number,2 (2008): 239 250.Fang, Karen; Arresting Cinema: Surveillance and the CityState in the Representation of Hong Kong; New Formations. 44.2 (2001): 12850. 18-SEP-14
ART402	MODERN ART	3-0-1-0-4	Art movements from 1840s to 1960s will be discussed in class from anaesthetic and socio-economic perspective. The study of movements will also be assisted with an exploration of philosophy of art wherever necessary. Art movements Impressionism, Post impressionism, Fauvism, Cubism, Futurism, Dadaism, Surrealism, Abstract expressionism, Pop art, Minimalism, Introduction to Post modernism. Philosophy of art Formalism (Clive Bell and Roger Fry), Dream in psycho analysis (Freud), Existentialism (Sartre, Camus), Modernism (Clement Greenberg). **Course Reference**: 1. Story of Modern Art, Cheney, Sheldon; 2. Art in theory: Charles Harrison & Paul Wood; 3. Abstract art: Anna Moszynska; 4. Shape ofthe pocket: John Berger; 5. Marg (Journal)6. Art India (Journal).
ART402A	MODERN ART	3-0-0-0-9	Art movements from 1840s to 1960s will be discussed in class from anaesthetic and socioeconomic perspective. The study of movements will also be assisted with an exploration of philosophy of art wherever necessary. Art movements Impressionism, Post impressionism, Fauvism, Cubism, Futurism, Dadaism, Surrealism, Abstract expressionism, Pop art, Minimalism, Introduction to Post modernism. Philosophy of art Formalism (Clive Bell and Roger Fry), Dream in psycho analysis (Freud), Existentialism (Sartre, Camus), Modernism (Clement Greenberg). **Course Reference**: 1. Story of Modern Art, Cheney, Sheldon; 2. Art in theory: Charles Harrison & Paul Wood; 3. Abstract art: Anna Moszynska; 4. Shape ofthe pocket: John Berger; 5. Marg (Journal); 6. Art India (Journal).
ART411	PRINCIPLES OF COMMUNICATION DESIGN	3-0-0-0-4	History of communication, Psychology of perception, Signs and symbols, Elements of visual display, Layout design, History of typography, Information structuring, Claymation, Visual branding, Case studies of campaigns. An overall understanding of above, mentioned areas will be assisted through related projects on composition, typography illustration techniques, story boarding, claymation, logo design and advertisement campaigns. **Course Reference**: 1. Art and Visual perception Rudolph Arnehiem; 2. Manufacturing Consent: The Political Economy of the Mass Media: Noam Chomsky; 3. Design and Form Johannes Itten; 4. The Visual Display of Quantitative Information: Edward

			Tufte; 5. Envisioning Information: Edward Tufte; 6. Visual Explanations: Images and Quantities, Evidence and Narrative: Edward Tufte; 7. Principles of Three Dimensional design Stephen Luecking; 8. Principles of 2D design Wucius Wong; 9. Principles of Form and Design Wucius Wong; 10. Pedagogical sketch book Paul K.leeII. Form (Journal); 11. MAG INDIA (online database of advertising and marketing) www.magindia.com.
ART411A	PRINCIPLES OF COMMUNICATION DESIGN	3-0-0-0-9	History of communication, Psychology of perception, Signs and symbols, Elements of visual display, Layout design, History of typography, Information structuring, Claymation, Visual branding, Case studies of campaigns. An overall understanding of above, mentioned areas will be assisted through related projects oncomposition, typography, illustration techniques, story boarding, claymation, logo design and advertisement campaigns. **Course Reference**: 1. Art and Visual perception Rudolph Arnehiem; 2. Manufacturing Consent: The Political Economy of the Mass Media: Noam Chomsky; 3. Design and Form Johannes Itten; 4. The Visual Display of Quantitative Information: Edward Tufte; 5. Envisioning Information: Edward Tufte; 6. Visual Explanations: Images and Quantities, Evidence and Narrative: Edward Tufte; 7. Principles of Three Dimensional design Stephen Luecking; 8. Principles of 2D design Wucius Wong; 9. Principles of Form and Design Wucius Wong; 10. Pedagogical sketch book Paul K.leeII. Form (Journal); 11. MAG INDIA (online database of advertising and marketing) www.magindia.com
ART701	METHODOLOGY: ART CRITICISM & APPRECIATION	3-0-0-0-4	To familiarize students with variety of methodological approach in art criticism and analysis. The course proposes to develop visual skills and analytical skills in writing about various forms of art in using concepts and terminology. It also would enable research student to exercise skills in observation of various formsof visual media. The methodology of criticism is base on some of the following authors John Dewey (Criticism and Perception), Barkan, Fidmans, Jack Hobbs, and Solomns Phenomenological Model of Criticism, and Ducasses Language of Feeling. The critical analysis would be based on Art and Perception, Principles of Style, Styles in 2 dimension and 3-dimension visual art.
ART701A	METHODOLOGY: ART CRITICISM & APPRECIATION	3-0-0-0-9	To familiarize students with variety of methodological approach in art criticism and analysis. The course proposes to develop visual skills and analytical skillsin writing about various forms of art in using concepts and terminology. It also would enable research student to exercise skills in observation of various formsof visual media. The methodology of criticism is based on some of the following authors

			John Dewey (Criticism and Perception), Barkan, Fidmans, Jack Hobbs, and Solomns Phenomenological Model of Criticism, and Ducasses Language of Feeling. The critical analysis would be based on Art and Perception, Principlesof Style, Styles in 2dimension and 3dimension visual art.
ART703A	STUDIO ART PRACTICES		The aim of the course is to expose the students to different mediums and methods of art practice. The course consists of four components based on four different fields: Painting, Cinematography, Graphics and Installation Art. Of the four components, any two shall be selected for teaching in a given semester.The course assessment will be based on a cumulative performance of the student in written examinations, which would primarily cover the theory, along with an exhibition/presentation at the end of each of the two components with an emphasis on the practice.The student will thus get at least half a semester to explore the potential of the medium with an emphasis on practice.
ART704A	ART A MEDIUM OF COMMUNICATION	2-0-3-0-9	Theory: Prehistoric Art; Traditional Art as Medum of Communication Religious Art, Buddhist Art, Christian Art, and Hindu Art; Critical analysis of the following theories/ articles Plato's; Art as Imitation; aristotle's;Theory on Art; Leo Tolstory's Theory of Art and;Art as the Communication of Feeling; David Hume's Of the Standard of Taste; susanne Langer's Art as Symbolic Expression: From Feeling and Form; Arthur Danto's;The Art World; POP Art and Comic Art; Art as Language of Expression in 2D and 3D media.
ART705A	MODERN FAR-EASTERN ART		This course is an introduction to many of the theories and methods that have been used by art historians to analyse the modern Far Eastern art. The visual foci will include the most popular works of art created by the East Asian modern artists as well as a variety of other visual media, including the museum setting and its strategies of display. This course also includes survey of the intellectual origins, artistic concerns and utopian programs of the Modern Art Movements in this region. Focusing on the years between 1950 and 2000, it will investigate a number of issues such as the relationship between the modernism in art (especially painting and sculpture) and the common responses of artists to the rapid transformation, industrialization and mechanization of the Far Eastern society. Thus, the course is based on trends in postmodern Far Eastern Art, the internationally acclaimed artists and their style and on dissemination and transformation of Far Eastern post modernist art in the world. This PG level course is designed to introduce students to the questions and debates that propel Far Eastern Art history and the methodologies that have shaped its shifts in strategy.

ART707A	INTRODUCTION TO CHINESE CINEMA		The primary objective of this course is to expose doctoral students to the art and visual culture of the Chinese Cinema. This PG level course will also assist them in comprehending and appreciating the wider horizon of the modern from its inception to the prevailing current trends and the scholarly works related to them.
ART711A	CREATIVE PAINTING-METHODOLOGY & PRACTICES		The aim of the course is to expose the postgraduate FineArts/Design students to various postmodern methods and mediums of creative painting. Finearts practices, specially painting is committed to greater artistic innovation and intellectual exhaustive. This course will emphasize critical thinking and strongly encourage art works that reexamines its context, material form and deeper conceptual method. The course aims to broaden the productive, conceptual, and critical faculties of students in their pursuit of careers as professional visual artists. This course is designed to prepare students for a professional exhibiting career and for teaching Fine Arts at the college level. Studio space (Fine Arts lab) will be provided to the students for regular lectures as well as their creative pursuit. Here students are expected to develop and understand their own creative processes, advance their painting practice and to communicate ideas and transfer skills within educational settings. The course assessment will be based on the cumulative performance of the student in written examinations, which would primarily cover the basic painting theory, along with a final exhibition/presentation at the end of this course with an emphasis on the practice. Final display of the artworks created by the student will require students to maintain a rigorous pace of creative research and establish a professional painting practice.
ENG112	ENGLISH LANGUAGE AND COMMUNICATION SKILLS	4-2-0-0-4	This course imparts training in the use of English language for communicative purposes, and aims to develop reading comprehension, writing, listening, andspoken language skills of the student. The Language Lab component seeks toprovide training in pronunciation and listening skills. Instruction is carried outin small tutorial groups for effective individual attention.
ENG112C	ENGLISH LANGUAGE AND COMMUNICATION SKILLS	3-1-0-0-11	Reading Comprehension Skills Discovering structure; identifying themes and subthemes; understanding and interpreting facts; distinguishing facts from opinions and specific from general statements; searchingfor information; drawing information and making, generalizations (14 Hrs). Writing Skills Process of Writing from prewriting activities through drafting and revision; Developinga composition using techniques such as definition, classification, analogy, etc; Descriptive, narrative, and argumentative techniques in writing (14 Hrs). Language Skills(a).

			Identifying, understanding and applying grammatical structures of English withspecial emphasis on Sentence structure, Diction, Agreement, Tense, and Point of view (b). Strategies: Economy, emphasis, clarity, concreteness, unity and coherence (7 Hrs). Spoken Language Skills Descriptive, narrative, and argumentative techniques in spoken language use (7 Hrs).
ENG112N	ENGLISH LANGUAGE AND COMPOSITION	3-1-0--4	This course imparts training in the use of English language for communicative purposes, and aims to develop reading comprehension, writing, listening, andspoken language skills of the student. The Language Lab component seeks toprovide training in pronunciation and listening skills. Instruction is carried out in small tutorial groups for effective individual attention.
ENG122	INTRODUCTION TO LINGUISTICS	3-1-0-0-4	Introducing Language; Natural Language and Artificial Languages; Natural Language and Animal Communication Systems; Evolution of Language; Acquisition of Language; Ancient Indian Linguistics; Modern Linguistics; Applied Linguistics. **Course Reference**:1. Hirschberg, S. and T. Hirschberg, Reflections on language, OUP, 1999; 2. Radford, R., Linguistics: An Introduction, CUP, 1999; 3. Jackendoff, Ray, Foundations of Language, OUP, 2000; 4. Bergmann, Anouschka; Katleen Currie Hall & Sharon Mariam Ross, Language Files.Ohio State University Press, 2007; 5. Selected papers on various topics.
ENG122A	INTRODUCTION TO LINGUISTICS	3-1-0-0-11	Introducing Language; Natural Language and Artificial Languages; NaturalLanguage and Animal Communication Systems; Evolution of Language; Acquisition ofLanguage; Ancient Indian Linguistics; Modern Linguistics; Applied Linguistics. **Course Reference**: 1. Hirschberg, S. and T. Hirschberg, Reflections on language, OUP, 1999; 2. Radford, R., Linguistics: An Introduction, CUP, 1999; 3. Jackendoff, Ray, Foundations of Language, OUP, 2000; 4. Bergmann, Anouschka; Katleen Currie Hall & Sharon Mariam Ross, Language Files.Ohio State University Press, 2007; 5. Selected papers on various topics.
ENG123	INTRODUCTION TO LITERATURE	3-1-0--4	The course will introduce students to literature through exposure to different literary genres within the three main categories of prose, poetry, and drama. The focus of thecourse will be on how to read a literary text in terms of its use of language and style as well itsthematic content. In the process, students will learn about the different approaches to literary analysis as a way of understanding, interpreting, and evaluating specific literary texts.
ENG123A	INTRODUCTION TO LITERATURE	3-1-0-0-11	The course will introduce students to literature through exposure to different literary genres within

			the three main categories of prose, poetry, and drama. The focus of thecourse will be on how to read a literary text in terms of its use of language and style as well its thematic content. In the process, students will learn about the different approaches to literary analysis as a way of understanding, interpreting, and evaluating specific literary texts.
ENG124	LANGUAGE AND SOCIETY	3-1-0-0-4	Problems of definition; Multilingual communities; Language variation; Language andidentity; Standardization; Language, culture and cognition; Language and social control; Methodological issues. Clyne, Michael, 2003. Dynamics of Language Contact, Cambridge University Press.Downes, William, 1998. Language and Society, Cambridge University Press.Romaine, S., 2000. Language in Society: An Introduction to Sociolinguistics, OUP.
ENG124A	LANGUAGE AND SOCIETY	3-1-0-0-11	Problems of definition; Multilingual communities; Language variation; Language andidentity; Standardization; Language, culture and cognition; Language and social control; Methodological issues. Clyne, Michael, 2003. Dynamics of Language Contact, Cambridge University Press.Downes, William, 1998. Language and Society, Cambridge University Press.Romaine, S., 2000. Language in Society: An Introduction to Socio linguistics, OUP.
ENG408A	SECOND LANGUAGE ACQUISITION	3-0-0-0-9	1. The foundations of SLA First language and Second language, acquiring L1 and L2, diversity in learning and learners, logical problem of language acquisition, different frameworks of SLA. 2. Inter language Nature of language, contrastive analysis, error analysis, monitor model, UG and SLA, learnability, critical period hypothesis, functional approaches, function form mapping. 3. Psycholinguistic aspects Language and brain, learning processes, competition models, connectionist approaches, differences in learners, learning strategies, effects of multilingualism. 4. Social contexts Communicative competence, microsocial and macro social factors, role ofinput and interaction, role of output. 5. Acquiring knowledge for L2 use Linguistic competence, linguistic performance, academic vs interpersonal competence, receptive activities, productive activities, discourse rules. 6. Teaching and second language learning Classroom language, processing instruction, teachability/ learnability, input manipulation, input enhancement.
ENG423A	CURRENT ISSUES IN LINGUISTICS		1.Conceptualising language: Internalist and externalist approaches to language design; 2.Language Faculty: Modularity, Optimality of design, Constraints on possiblegrammars, Interface systems; 3.Conceptual and linguistic architecture: Amodularity, Spatial and temporal cognition, Linguistic mappings, Lexicalization patterns, Crosslinguistic variation, Diachronicshifts, Multimodal cognition, Bilingual

			cognitive and linguistic processing; 4.Language Acquisition: Perceptual grounding, embodiment, perceptual and linguistic processes; 5.Speech acts: Rhetorical relations, metaphor, intentionality and implicature; 6.Discourse: Linguistic and cultural boundaries, Language and identity, Language andeducation, Discourse, ideology and control. **Course Reference**: 1. Chomsky, N. New Horizons in the Study of Language and Mind. Cambridge UniversityPress. 2000; 2. Chomsky, N. Architecture of Language. Oxford University Press. 2001; 3. Huang, Y. Pragmatics. Oxford University Press. 2007; 4. Jacknedoff, R. Foundations of Language: Brain, Meaning, Grammar, Evolution. OxfordUniversity Press. 2002; 5. Langacker, R.W. Grammar and Conceptualisation. De Gruyter.1999; 6.Pinker. S. Language Cognition and Human Nature. Oxford University Press. 2013; 7. Talmy, L. Cognitive Semantics vol. 1 and 2, MIT Press. 2000.
ENG431	THE INDO-ANGLIAN NOVEL	3-1-0--4	The genre of the novel is seen as a colonial legacy as it developed in Indiasince the arrival of the British. The Indian English novel bears the colonial imprint more as it is written in the colonise's language. The course attempts to understand this geme that is considered foreign in India, in terms of both geme as well as language. However, the Indian English novel has acquired quite a reputation in world literature today and has writers who have remarkable felicity of style and catholicity of subject matter. The course will trace the development of the Indian English novel from its origin to the present day, focusing on critical junctures that mark this progress. Novels that have made a mark nationally and internationally will be used to exemplify this. Mehrotra, Arvind Krishna. History of Indian literature in English. New York: Columbia University Press, 2003. Mukherjee, Meenakshi. The Twice Born Fiction: Themes and Techniques of the Indian Novel in English. 1971. Delhi: Pencraft International, 2009.
ENG432	LITERATURE AND IDEOLOGY	3-1-0--4	This course will engage with the concept of Ideology, and its relationship with literature. Beginning with a definition of Ideology and its various subcategories, the course will go on to examine how ideology impacts both the creation andthe reception of literary texts, both explicitly and implicitly. In the process, we will analyse the many different kinds of relationships that a literary text may have with ideology, ranging from propagation and elaboration, to refutation and critique. We willalso attempt to understand how ideology creates and impacts different schools of literary criticism, and its relationship with aesthetic modes ofliterary reception. **Course Reference:** 1. Eagleton, Terry. Criticism and Ideology. New York: Verso, 1978.Hawkes, David.

			Ideology. London: Routledge, 2003; 2. Williams, Raymond. Keywords: A Vocabulary of Culture and Society. New York: Oxford University Press, 1983.
ENG432A	LITERATURE AND IDEOLOGY	3-0-0--9	This course will engage with the concept of Ideology, and its relationship with literature. Beginning with a definition of Ideology and its various sub categories, the course will go on to examine how ideology impacts both the creation andthe reception of literary texts, both explicitly and implicitly. In the process, we will analyse the many different kinds of relationships that a literary text may have with ideology, ranging from propagation and elaboration, to refutation and critique. We willalso attempt to understand how ideology creates and impacts different schools of literary criticism, and its relationship with aesthetic modes ofliterary reception. Eagleton, Terry. Criticism and Ideology. New York: Verso, 1978.Hawkes, David. Ideology. London: Routledge, 2003.Williams, Raymond. Keywords: A Vocabulary of Culture and Society. New York: Oxford University Press, 1983.
ENG433	MODERN DRAMA	3-1-0--4	1. Introduction to Drama 2. An Overview of the Theatre: 3. European Drama & European Society 4. Ibsen’s The Wild Duck 5. Strindberg’s The Father 6. Russian Society in the 191h Century7. Chekov’s The Cherry Orchard; 8. Pirandello’s Six Characters; 9. Absurd Drama: An Overview10. Beckett’s Waiting/or Godot; 11. An Overview of American Drama; 12. Miller’s Death of a Salesman; 13. Williams’s A Streetcar Named Desire 1. Weiss. Drama in the Modern World. 2. Gassner, J. Treasury of the Theatre.
ENG433A	MODERN DRAMA	3-0-0-0-9	1. Introduction to Drama 2. An Overview of the Theatre: 3. European Drama & European Society 4. Ibsen’s The Wild Duck 5. Strindberg’s The Father 6. Russian Society in the 191h Century 7. Chekov’s The Cherry Orchard 8. Pirandello’s Six Characters 9. Absurd Drama: An Overview 10. Beckett’s Waiting/or Godot 11. An Overview of American Drama 12. Miller’s Death of a Salesman 13. Williams’s A Streetcar Named Desire 1. Weiss. Drama in the Modern World. 2. Gassner, J. Treasury of the Theatre.
ENG434	MODERN BRITISH AND AMERICAN NOVEL	3-1-0--4	1. Introduction to the Novel 2. Novel in the Anglo-American literary tradition 3. Major concerns in 19th & 20th century British, American Novel 4. Romance & the Novel in America 5. Hawthorne’s The Scarlet Letter 6. Modernism & the English Novel 7. Art & the Artist in Modernist Novel 8. Joyce’s A Portrait of the Artist 9. Feminism and Woolf. 10. Woolrs To the Lighthouse 11. Forster’s A Passage to India 12. American Modernism 13. Fitzgerald’s Tender is the Night 14. Hemingway’s A Farewell to Arms 15 Summing Up 1. Margaret Drabble. The Oxford

			Companion to English Literature.2. The Cambridge Companion to American Literature.
ENG434A	MODERN BRITISH AND AMERICAN NOVEL	3-0-0-0-9	1. Introduction to the Novel. Novel in the Anglo-American literary tradition. Major concerns in 19th & 20th century British, American NoveL. Romance and the Novel in America. Hawthorne's The Scarlet Letter. Modernism and the English Novel. Art and the Artist in Modernist Novel. Joyce's A Portrait of the Artist. Feminism and Woolf. Woolrs To the Lighthouse. Forster's A Passage to India. American Modernism. Fitzgerald's Tender is the Night. Hemingway's A Farewell to Arms Summing Up 1. Margaret Drabble. The Oxford Companion to English Literature. The Cambridge Companion to American Literature.
ENG435	TOPICS IN LITERARY MOVEMENTS	3-1-0--4	The literature of any language is usually categorized in terms of movements, or discernible trends in style and theme at a particular point in the course ofits development. These trends in literature constitute a literary movement. The major movements in Anglo American literature are Romanticism, Neoclassicism, Realism, Naturalism, Modernism and Postmodernism. These are but generalized categories that actually include a wide variety of topics which have been dealt with in diverse ways by different writers. The course includes a study of literary movements in general, and more detailed examination of the topics that are subsumed under particular movements. It will also take in to account the changing perspectives on writing and writers that usually change according to the movements. Each topic will be illustrated using a seminal textand writer. Peck, John and Martin Coyle. A Brief History of English Literature. New York: Palgrave Macmillan, 2002.Sanders, Andrew. Short Oxford History of English Literature. Oxford: Oxford University Press, 2004.
ENG435A	TOPICS IN LITERARY MOVEMENTS	3-0-0-0-9	The literature of any language is usually categorized in terms of movements, or discernible trends in style and theme at a particular point in the course of its development. These trends in literature constitute a literary movement. The major movements in Anglo American literature are Romanticism, Neoclassicism, Realism, Naturalism, Modernism and Postmodernism. These are but generalized categories that actually include a wide variety of topics which have been dealt with in diverse ways by different writers. The course includes a study of literary movements in general, and more detailed examination of the topics that are subsumed under particular movements. It will also take in to account the changing perspectives on writing and writers that usually change according to the movements. Each topic will be illustrated using a seminal textand writer.

			Peck, John and Martin Coyle. A Brief History of English Literature. New York: Palgrave Macmillan, 2002.Sanders, Andrew. Short Oxford History of English Literature. Oxford: Oxford UniversityPress, 2004.
ENG436	THE WRITER'S VISION OF THE FUTURE	3-0-0--4	This course identifies and defines visionary literature through a broad range of disciplines and/or literary genres. Open to engaging with texts from different domains, from philosophy to economics to science fiction and fantasy, the course analyses the relationship between visionary writing and the concepts of utopia as well asprophecy. In the process, the course examines the ways in which the visions articulated by such texts intersect with their and our realities, their purpose and effectiveness, as well as their relevance for social change. No specific textbook or reference material. The specific texts chosen for the course in a particular semester will determine the appropriate reference materials.
ENG436A	THE WRITER'S VISION OF THE FUTURE	3-0-0-0-9	This course identifies and defines visionary literature through a broad range of disciplines and/or literary genres. Open to engaging with texts from different domains, from philosophy to economics to science fiction and fantasy, the course analyses the relationship between visionary writing and the concepts of utopia as well asprophecy. In the process, the course examines the ways in which the visions articulated by such texts intersect with their and our realities, their purpose and effectiveness, as well as their relevance for social change. No specific textbook or reference material. The specific texts chosen for the course in a particular semester will determine the appropriate reference materials.
ENG437	INDIAN LITERATURE	3-1-0--4	The course attempts to give a crosssection of Indian literature which is diverse, multilingual, and spans a vast period of time. The broad areas that will be covered are the origin and development of genres like drama and poetry in ancient India, Bhakti poetry, therise of the novel, and the themes and issues in contemporary literature written in the various Indian languages. These will be exemplified with the help of relevant literary texts from different ages and different parts of the country. It will also critically examine the attempt to homogenize the diverse strands that go into the making of the literature of India. The focus will be on Indian language texts, including fiction, poems and plays in English translation. No specific textbook. Selections can include Sangam poetry, Bhakti poetry, and works of writers like Premchand, Rabindranath Tagore, Ismat Chugtai, Dilip Chitre, M. T. Vasudevan Nair, and Mahasweta Devi.
ENG437A	INDIAN LITERATURE	3-0-0-0-9	The course attempts to give a crosssection of Indian literature which is diverse, multilingual, and spans a

			vast period of time. The broad areas that will be covered are the origin and development of genres like drama and poetry in ancient India, Bhakti poetry, therise of the novel, and the themes and issues in contemporary literature written in the various Indian languages. These will be exemplified with the help of relevant literary texts from different ages and different parts of the country. It will also critically examine the attempt to homogenize the diverse strands that go into the making of the literature of India. The focus will be on Indian language texts, including fiction, poems and plays in English translation. No specific textbook. Selections can include Sangam poetry, Bhakti poetry, and works of writers like Premchand, Rabindranath Tagore, Ismat Chugtai, Dilip Chitre, M. T. Vasudevan Nair, and Mahasweta Devi.
ENG438	POSTCOLONIAL LITERATURE	3-0-0-0-4	This course will unpack the many meanings of the term's; postcolonial; through a study of literature that has emerged from the colonial encounter in various parts of the world.Focused mainly on literature written in English (and hence on the British empire within ahistorical context), the course will examine works from Africa, the Caribbean, and India, in addition to British literature itself, to understand how such literature deals with and/or resists the experience and legacy of colonialsim. In addition, the course will engage with contemporary literature, primarily from the US and India, to understand the relevance of postcolonialism within current global relations between the North and the South. I) Loomba, Ania. Colonialism/Postcolonialism. New York: Routledge, 1998. 2) The Empire Writes Back: Theory and Practice in PostColonial Literatures. Edited by Bill Ashcroft, Gareth Griffiths, Helen Tiffin. New York: Routledge, 2002.
ENG438A	POSTCOLONIAL LITERATURE	3-0-0-0-9	This course will unpack the many meanings of the terms; postcolonial through a study of literature that has emerged from the colonial encounter in various parts of the world. Focused mainly on literature written in English (and hence on the British empire within ahistorical context), the course will examine works from Africa, the Caribbean, and India, in addition to British literature itself, to understand how such literature deals with and/or resists the experience and legacy of colonialsim. In addition, the course will engage with contemporary literature, primarily from the US and India, to understand the relevance of postcolonialism within current global relations between the North and the South. **Course Reference**: 1. Loomba, Ania. Colonialism/Postcolonialism. New York: Routledge, 1998; 2. The Empire Writes Back: Theory and Practice in Post Colonial Literatures. Edited by Bill Ashcroft, Gareth Griffiths, Helen Tiffin. New York:

			Routledge, 2002.
ENG439	LITERATURE AND CENSORSHIP	3-0-0--4	Censorship is defined as the restrictions that are imposed on the writer and writings by centres of power like the state, religious institutions or other social organizations. These external restrictions can lead to self imposed censorship, in the form of inhibitions which prevent the writer from expressing his I her views and thoughts openly. The course attempts to understand why writing is perceived as a threat to established institutions like the state or organized religion, and the impact of such restrictions on writing. Besides, it also analyzes the process of censorship as it has been practiced, and still is practiced, in various parts of the world. The efficacy of this restrictive measure will be evaluated with the help oftexts that have created controversies for going against accepted notions of morality or religious beliefs. Green, Jonathon and Nicholas Karolides. **Course Reference**:1. The Encyclopedia on Censorship. New York Info base Publishers, 2005; 2. Jansen, Sue Curry. Censorship: The Knot that binds Power and Knowledge. Oxford: Oxford University Press, 1991; 3. Nadaff, Ramona A. Exiling the Poets: The Production of Censorship in Plato's Republic.Chicago: University of Chicago Press, 2003.
ENG439A	LITERATURE AND CENSORSHIP	3-0-0-0-9	Censorship is defined as the restrictions that are imposed on the writer and writings by centres of power like the state, religious institutions or other social organizations. These external restrictions can lead to self imposed censorship, in the form of inhibitions which prevent the writer from expressing his I her views and thoughts openly. The course attempts to understand why writing is perceived as a threat to established institutions like the state or organized religion, and the impact of such restrictions on writing. Besides, it also analyzes the process of censorship as it has been practiced, and still is practiced, in various parts of the world. The efficacy of this restrictive measure will be evaluated with the help oftexts that have created controversies for going against accepted notions of morality or religious beliefs. Green, Jonathon and Nicholas Karolides. **Course Reference**:1 The Encyclopedia on Censorship. New York: Info base Publishers, 2005; 2. Jansen, Sue Curry. Censorship: The Knot that binds Power and Knowledge. Oxford: Oxford University Press, 1991; 3. Nadaff, Ramona A. Exiling the Poets: The Production of Censorship in Plato's Republic.Chicago: University of Chicago Press, 2003.
ENG440	TOPICS IN LITERARY GENRES	3-1-0--4	This course will explore the concept of literary genre and its implications for both the production and reception of literary works. Delving beyond the broad divisions of poetry, prose, and drama, this course will

			investigate the formand content of specific interrelated genres such as crime fiction/rogue fiction/detective fiction/Nair or romance/gothic/science fiction/fantasy, etc. It will situate these genres within a historical context and explore their regional variations by studying Western texts alongside nonWestern ones from the same genre. In the process, the course will examine the ways in which various social categories influence the contours of various literary genres and the extent to which genres are contained within cultural temporal boundaries. No specific textbook. Reference material will be decided on the basis of the specific group of genres under study during a particular semester, and may include the following: **Course Reference**: 1. Frow, John. Genre. New York: Routledge, 2005; 2. Todorov, Tzvetan. Genres in Discourse. New York: Cambridge University Press, 1990.
ENG440A	TOPICS IN LITERARY GENRES	3-0-0-0-9	This course will explore the concept of literary genre and its implications for both the production and reception of literary works. Delving beyond the broad divisions of poetry, prose, and drama, this course will investigate the formand content of specific interrelated genres such as crime fiction/rogue fiction/detective fiction/Nair or romance/gothic/science fiction/fantasy, etc. It will situate these genres within a historical context and explore their regional variations by studying Western texts alongside non-western ones from the same genre. In the process, the course will examinethe ways in which various social categories influence the contours of various literary genres and the extent to which genres are contained within cultural temporal boundaries. No specific textbook. Reference material will be decided on the basis of the specific group of genres under study during a particular semester, and may include the following: **Course Reference**: 1. Frow, John. Genre. New York: Routledge, 2005; 2. Todorov, Tzvetan. Genres in Discourse. New York: Cambridge UniversityPress, 1990.
ENG443	NATURAL LANGUAGE SEMANTICS	3-1-0--4	Philosophical and linguistic approaches to semantics; Semantic structure and its computational modeling; Lexical semantics; Logical form of naturallanguage; Anaphoric dependencies; Pragmatic structure; Cognitive grammar and cognitive semantics Semantics: Philosophical and Linguistic approaches to Semantics. Semantic Structure and its Computational Modelling: Semantics 6 Pragmatics Distinction, Syntax Semantics Interface: Syntactic and Semantic Parsing, HPSG, Frame Net Semantics Lexical Semantics: Lexical Under determination, Interlexical Relations, Lexical Conceptual Structures,

			Generative Lexicons, Argument Structure, Event Structure and Qualia Structure, WordNet and Generative Lexicons Logical Form of Natural Language. Propositional Structure, Quantification, Quasi quantification Anaphoric Dependencies: Pronouns and Reflexives, Ellipsis and other Lexical Gaps Pragmatic Structure: Implicature and Nonliteralness, Modelling Pragmatic Knowledge, Discourse Representation Theory/Situation Semantics Cognitive Grammar and Cognitive Semantics.
ENG445	LITERATURE & THE INDIVIDUAL	3-1-0-0-4	The precarious role of an individual in a dynamic society totalitarian, democratic, technological, globalized, etc has been an intense and perennial subject of concern in literature. Many literary works deal with such problems of humanity as the constraints of individual freedom, loss of identity, search for self, struggle for individual survival, pangs of isolation and alienation, and attempts for salvaging sanity from a maddeningly disordered world. These works, through fables, fantasies, realistic as well as futuristic representations, interrogate, probe into the prevalent values, and affect changes in the lives of individuals, and by extension, their societies. Apart from a utopian prophecy of deferred but ultimate triumph of humanity, these literary works often inspire, and instill in the readers enduring ideas, ideals, and values. The works for study in the course includes the classics of world literature from George Orwell, Ernest Hemingway, Herman Hesse, R. K. Narayan, Saul Bellow, Somerset Maugham and Upamanyu Chatterjee to semiphilosophical and popular texts of Ayn Rand, Khalil Gibran, Paulo Coelho, Richard Bach and Robert Pirsig.
ENG445A	LITERATURE & THE INDIVIDUAL	3-0-0-0-9	The precarious role of an individual in a dynamic society totalitarian, democratic, technological, globalized, etchas been an intense and perennial subject of concern in literature. Many literary works deal with such problems of humanity as the constraints of individual freedom, loss of identity, search for self, struggle for individual survival, pangs of isolation and alienation, and attempts for salvaging sanity from a maddeningly disordered world. These works, through fables, fantasies, realistic as well as futuristic representations, interrogate, probe into the prevalent values, and affect changes in the lives of individuals, and by extension, their societies. Apart from a utopian prophecy of deferred but ultimate triumph of humanity, these literary works often inspire, and instill in the readers enduring ideas, ideals, and values. Theworks for study in the course include the classics of world literature from George Orwell, Ernest Hemingway, Herman Hesse, R. K. Narayan, Saul Bellow, Somerset Maugham and

			Upamanyu Chatterjee to semiphilosophical and popular texts of Ayn Rand, Khalil Gibran, Paulo Coelho, Richard Bach and Robert Pirsig.
ENG446	LITERATURE & ADAPTATION	3-1-0-0-4	This course will examine the processes and politics of adaptation as textstravel across genres, media, and cultures. Focusing primarily on literary texts, graphic narrative sand films, it will investigate the different vocabularies of each media and see how meaning is transformed as it travels across different languages. In the process, it will delve into topics suchas the semiotics of translation, the fidelity debate, the relationship between adaptation and appropriation, ideology and intention in the creation of adaptations etc. **Course Reference**: 1. Hutcheon, Linda. A Theory of Adaptation. New York: Routledge, 2006; 2. Sanders, Julie. Adaptation and Appropriation. New York: Routledge, 2006.
ENG446A	LITERATURE & ADAPTATION	3-0-0-0-9	This course will examine the processes and politics of adaptation as texts travel across genres, media, and cultures. Focusing primarily on literary texts, graphic narratives and films, it will investigate the different vocabularies of each media and see how meaning is transformed as it travels across different languages. In the process, it will delve into topics such as the semiotics of translation, the fidelity; debate, the relationship between adaptation and appropriation, ideology and intention in the creation of adaptations etc. **Course Reference**: 1. Hutcheon, Linda. A Theory of Adaptation. New York: Routledge, 2006; 2, Sanders, Julie. Adaptation and Appropriation. New York: Routledge, 2006.
ENG448	LANGAUGES OF SOUTH ASIA	3-0-0-0-4	South Asia as a linguistic region: Indo Aryan languages, Dravidian languages, Tibeto Burman languages, Munda languages, Languages of the Andamans Convergence features Language contact. The role of English Orality, literacy and writing systems Language and Discourse 1. Languages in Diaspora 2 Language Conflicts 2. Abbi, Anvita. 1997. Languages of Tribal and Indigenous Peoples of India: TheEthnic Space. MLBDAbbi, Anvita. 2006. Endangered Languages of the Andaman Islands. Lin com Europa.
ENG448A	LANGAUGES OF SOUTH ASIA	3-0-0-0-9	South Asia as a linguistic region: Indo Aryan languages, Dravidian languages, Tibeto Burman languages, Munda languages, Languages of the Andamans, Convergence features Language contact. The role of English Orality, literacy and writing systems. Language and Discourse **Course Reference**: 1. Languages in Diaspora. Language Conflicts; 2. Abbi, Anvita. 1997; 3. Languages of Tribal and Indigenous Peoples of India:

			TheEthnic Space. MLBD Abbi, Anvita. 2006. Endangered Languages of the Andaman Islands. Lin com Europa.
ENG450A	ACADEMIC WRITING	ENG450A	Course Content: (Number of proposed lectures is given in brackets): 1.Getting started (03): Analysing issues, identifying the purpose ofwrite up and the target audience, identifying the relevant materials, gathering and organizing the ideas; 2.Using resources (06): Critically reading the relevant materials,notemaking, paraphrasing, summarising, evaluating, combing available resources; 3.Paragraphs and paragraphing (06): Why to make paragraphs, how to make paragraphs, identifying topic sentence and details, understanding coherence, analysing cohesive devices, links within and across paragraphs; 4.Language and style (07): Cohesive devices, passives, prepositions,referring verbs, tenses, punctuation, relevant style (hedging, complexity, formality, precision); 5.Organizing the writeup (07): Parts of a writeup (introduction, mainbody and conclusion), narration, description, explanation, argumentation, instruction, expressing opinions; 6.Writing models (06): Argumentative and descriptive essays, emails,formal letters, invitations, notices, posters; 7.Common mistakes (04): Mistakes in reasoning, mistakes in grammar and punctuation; 8.Revision (03): Getting feedback, Rereading and rewriting,proofreading, finalising, avoiding plagiarism. **Course Reference**: 1. Bailey, S. (2004). Academic writing: A practical guide for students. Routledge Falmer: New York.Giltrow, J. Gooding, R., Burgoyne, B., & Sawatsky, M. (2009). Academic writing: An introduction (2nd edn.). Brodview Press: Ontario.Hilton, C. & Hyder, M., (1992a).; 2. Getting to grips with punctuation and grammar. BPP (Letts Educational) Ltd: London.Hilton, C. & Hyder, M., (1992b).; 3. Getting to Grips with Spelling. BPP (Letts Educational) Ltd: London. University of Essex (2008). How to improve your academic writing. Retrieved on August 13, 2014.
ENG451	GLOBAL COMMUNICATION	3-0-1-0-4	The focus of the course is on the use of English language in national/multinational corporations and communication mediated through mobile, telephone, email, internet and other advanced technologies. Significant topics for discussion include: 1. Communication, Culture, Power 2. Current World Trends in Media Communication 3. Ethnographic Perceptions 4. Global Imbalances in Informational and Cultural Exchange 5. Benefits of Intercultural Communication 6. Intercultural Competence 7. Interpersonal Communication 8. Environments and Information Load 9. CrossCultural Communication Styles 10. Etiquettes for the Net 11. Qualities of Effective Report Writing 12. Writing Effective Emails

			13. Communication Information Through Visuals 14. Channels of Nonverbal Communication 15. Competence in Interviewing Contexts 16. Confidence in Use of Body Language.
ENG452A	LINGUISTIC TYPOLOGY	3-0-0-0-5	Methodology and Unversal Phomological Typology. Morphological Typology. Constiuent Order Typology. Grammatical Relation and Alignment. Hierarchies and Semantic Maps. Typology of World Classes. Typology of Valence. Typology of Negation. Typology of Relative Clauses
ENG453A	LINGUISTIC UNIVERSALS	3-0-0-0-5	Theoretica; and Emperical Approaches to Linguistic Universals. Argument from Linguistic Typology and Epistemology. Absolute Statistical and Implicational Universals. Explanatory Adequacy and the Universal Grammer.Formal and Substantive Universals. Faculty of Language Principal and Parameters, The Minimalist Programme.
ENG456	CLIMATE FICTION AND FILMS	3-0-0-0-4	I.Introduction to Climate Change. II. Geological Causes of Climate Change. III. Anthropogenic Causes of Climate Change. IV. Climate Skepticism; Threat Perception and Underlying Politics. V. Effects of Climate Change. VI. Cocepts of Ecohorror. VII. Dystopian Doom: The Irreversible Damage. VIII. Fictional Representations of Climate Change: Ecofiction/Ecofabulism. IX. Film Representations of Climate Change: Enviropocalypse, Postapocalypse. X. Concepts, Themes and Issues in Climate Fiction. XI. What is Wrong with Cliflicks? XII. Impact of Climate Change on Species Survival: Scarcity of Resources and Hunger Games. XIII. Future Possibilities: Gaia and Geoengineering. XIV. Sustainability and Climate Responsibility. XV. Reality Check: Climate Politics that Avert Possible Solutions. Atwood, Margaret. Oryx and Crake. Toronto: McClelland & Stewart Limited, 2003. Maddaddam. Toronto: McClelland & Stewart Limited, 2013. Budyko, M.I. and Yu. A. Izrael, Eds. Anthropogenic Climatic Change. Tucson: The Univ. of Arizona Press, 1991; etal. Global Climatic Catastrophes. Trans. V.G. Yanuta. New York: SpringerVerlag, 1986.Bacigalupi, Paolo. The Windup Girl. San Francisco, CA: Night Shade Books, 2009. Clark, Timothy, The Cambridge Introduction to Literature and the Environment. Cambridge: Cambridge Univ. Press, 2011. Crichton, Michael. State of Fear. New York: Harper Collins, 2004. Fleming, James ROdger. Fixing the Sky. New York: Columbia Univ. Press 2010.Fraser, Evan D.G. cfoodcrisis: A Graphic Novel about Global Food Security. Guelph, Ontrario: Evan Fraser,2014. <https://feedingninebillion.com/foodcrisis>Glass, Matthew. Ultimatum. New York: Atlantic Monthly Press, 2009. McNeil, Jean. The Ice Lovers. Toronto: MacArthur & Co., 2009.

ENG456A	CLIMATE FICTION AND FILMS	3-0-0-0-9	I.Introduction to Climate Change. II. Geological Causes of Climate Change. III. Anthropogenic Causes of Climate Change. IV. Climate Skepticism; Threat Perception and Underlying Politics. V. Effects of Climate Change. VI. Cocepts of Ecohorror. VII. Dystopian Doom: The Irreversible Damage. VIII. Fictional Representations of Climate Change: Ecofiction/Ecofabulism. IX. Film Representations of Climate Change: Enviropocalypse, Postapocalypse. X. Concepts, Themes and Issues in Climate Fiction. XI. What is Wrong with Cliflicks? XII. Impact of Climate Change on Species Survival: Scarcity of Resources and Hunger Games. XIII. Future Possibilities: Gaia and Geoengineering. XIV. Sustainability and Climate Responsibility. XV. Reality Check: Climate Politics that Avert Possible Solutions. Atwood, Margaret. Oryx and Crake. TOronto: McClelland & Stewart Limited, 2003. Maddaddam. Toronto: McClelland & Stewart Limited, 2013. Budyko, M.I. and Yu. A. Izrael, Eds. Anthropogenic Climatic Change. Tucson: The Univ. of Arizona Press, 1991; et al. Global Climatic Catastrophes. Trans. V.G. Yanuta. New York: SpringerVerlag, 1986.Bacigalupi, Paolo. The Windup Girl. San Francisco, CA: Night Shade Books, 2009. Clark, Timothy, The Cambridge Introduction to Literature and the Environment. Cambridge: Cambridge Univ. Press, 2011. Crichton, Michael. State of Fear. New York: Harper Collins, 2004. Fleming, James ROdger. Fixing the Sky. New York: Columbia Univ. Press 2010.Fraser, Evan D.G. foodcrisis: A Graphic Novel about Global Food Security. Guelph, Ontrario: Evan Fraser, 2014. Glass, Matthew. Ultimatum. New York: Atlantic Monthly Press, 2009. McNeil, Jean. The Ice Lovers. Toronto: MacArthur & Co., 2009.
ENG457	FILM AND THEORY	3-0-0-0-4	The Uncanny: omnipotence of thought; the doppelganger, the evil eye, Freud's theory of the Oedipus complex, Mulvey's concept of scopophia. Analysis of; Vertigo; and; Rear Window; Melodrama and Tears: Eyeline gaze, the unabandoned wish; undermotivated events; function of fate, determinism. The use of events happening;too late; Analysis of Douglas Sirks;; All That Heaven Allows and Written on the Wind; Discussion of;Freud 's Masterplot on repetition (and the repetition compulsion), precedence and consequence in the creation of;linkage; Movement toward closed and legible wholes under;the mandate of desire; Analysis of Picnic and; Splendor in the Grass; Krips and Zizek on Lacan: Discussion of unrealistic anxiety, the other and the Big Other, lack in the visual field, internalization, the ego ideal. Analysis of Strangers on a Train; Brooks, Peter.; Freud's masterplot; Yale French Studies (1977): 280300. Cook, Pam.;

			Duplicity in Mildred Pierce; Women in film noir (1978): 6882. Creed, Barbara. The monstrousfeminine; Film, feminism, psychoanalysis. Psychology Press, 1993. Creed, Barbara; Film and psychoanalysis; The Oxford Guide to Film Studies (1998): 7790. De Lauretis, Teresa. Technologies of gender: Essays on theory, film, and fiction. Vol. 441. Indiana University Press, 1987. Heung, Marina.; What's the Matter with Sara Jane? Daughters and Mothers in Douglas Sirk; Imitation of Life; Cinema journal (1987): 2143. Krips, Henry; The politics of the gaze: Foucault, Lacan and Zizek; Culture Unbound 2 (2010): 91102. Loren, Scott; Selffashioning, Freedom, and the Problem of History: the return of noir; European journal of American studies3.1 (2008).
ENG457A	FILM AND THEORY	3-0-0-0-9	The Uncanny: omnipotence of thought; the doppel ganger, the evil eye, Freud's theory of the Oedipus complex, Mulvey's concept of scopophia. Analysis of Vertigo and Rear Window; Melodrama and Tears: Eyeline gaze, the unabandoned wish, uundermotivated events function of fate, determinism. The use of events happening too late; Analysis of Douglas Sirkss All That Heaven Allows; and; Written on the Wind; Discussion of; Masterplot; on repetition (and the repetition compulsion), precedence and consequence in the creation of; linkage; Movement toward closed and legible wholes under the mandate of desire; Analysis of Picnic; and; Splendor in the Grass; Krips and Zizek on Lacan: Discussion of unrealistic anxiety, the other and the Big Other, lack in the visual field, internalization, the ego ideal. Analysis of; Strangers on a Train; Brooks, Peter.; Freud's masterplot; Yale French Studies (1977): 280300. Cook, Pam.; Duplicity in Mildred Pierce; Women in film noir (1978): 6882. Creed, Barbara. The monstrous feminine; Film, feminism, psychoanalysis. Psychology Press, 1993. Creed, Barbara.; Film and psychoanalysis; The Oxford Guide to Film Studies (1998): 7790. De Lauretis, Teresa. Technologies of gender: Essays on theory, film, and fiction. Vol. 441. Indiana University Press, 1987. Heung, Marina.; What the Matter with Sara Jane: Daughters and Mothers in Douglas Sirk; Imitation of Life; Cinema journal (1987): 2143. Krips, Henry. The politics of the gaze: Foucault, Lacan and Zizek; Culture Unbound 2 (2010): 91102. Loren, Scott; Selffashioning, Freedom, and the Problem of History: the return of noir; European journal of American studies 3.1 (2008).
ENG701	FUNDAMENTALS OF MODERN LINGUISTICS	3-0-0-0-4	Structure of language; statistical structure and information theory; phonetics, phonemics and the distinctive feature theory; grammatical structure; ICanalysis; phrase structure and transformational grammars; grammatical categoriesand functions;

			semantics.
ENG701A	FUNDAMENTALS OF MODERN LINGUISTICS	3-0-0-0-9	Structure of language; statistical structure and information theory; phonetics, phonemics and the distinctive feature theory; grammatical structure; IC analysis; phrase structure and transformational grammars; grammatical categories and functions; semantics.
ENG703	STRUCTURE OF MODERN ENGLISH	3-0-0--4	Varieties of English; registers and dialects; phonetics of English; phonetic transcription; grammar of English; morphology and syntax; the transformational generative approach to the phonology and syntax of English.
ENG708A	APPLIED LINGUISTICS	3-0-0-0-9	Modern developments in applied linguistics particularly in the fields of language learning and teaching; psychological, sociological, lingustic, and pedagogical aspects of language learning, second language learning; teaching and learning of English as a second language in India; course design, teaching of language skills; contrastive analysis, error analysis, programmed instruction, audiovisual aids, language testing etc.
ENG709	LINGUISTIC ANALYSIS	3-0-0--4	This course attempts to apply the principles of linguistic analysis to real language data. It covers phonological, lexical, syntactic and semantic analysis and involves some amount of fieldwork.
ENG709A	LINGUISTIC ANALYSIS	3-0-0-0-9	This course attempts to apply the principles of lingustic analysis to real language data. It covers phonologica, lexical, syntactic and semantic analysis and involves some amount of fieldwork.
ENG711A	INDIAN WRITING IN ENGLISH	3-0-0-0-9	Selected Indian writings in English or translated from Indian Languages will be used for an extensive examination of some significant themes, e.g., rejection of old taboos, industrialization and its attendant problems, growth of secularism, social changes, bureaucracy and its role, generation gap, etc.
ENG712	LITERATURE AND SOCIETY	3-0-0--4	This course will study in depth and detail the various modes of interaction between literature and society. The primary emphasis will be on some of the major themes and social concerns (such as individual and society, alienation, technological progress and its human consequences free will and determinism) which have preoccupied creative writers.
ENG715	METHODOLOGY OF TEACHING AND RESEARCH IN LITERATURE	3-0-0--4	This course will study selected pedagogical material on the teaching of literature with a view to acquainting the student with the major theories and techniques of literary study as an academic discipline. It will also seek to familiarise the student with the basic tools and materials of literary research.
ENG715A	METHODOLOGY OF TEACHING AND RESEARCH IN	3-0-0-0-9	This course will study selected pedagogical material on the teaching of literature with a view to acquainting the student with the major theories and techniques of

	LITERATURE		literary study as an academic discipline. It will also seek to familiarise the student with the basic tools and materials of literary research.
ENG716	INDIVIDUAL PROJECTS		This course is intended to provide the students an opportunity to take up on their own a short - term field work or library project, with constant guidance from the Instructor. Evaluation will depend on the final product and interim reports.
ENG716A	INDIVIDUAL PROJECTS		This course is intended to provide the students an opportunity to take up ontheir own a short-term field work or library project, with constant guidance from the Instructor. Evaluation will depend on the final product and interim reports.
ENG719	AMERICAN RENAISSANCE		The course will study the major themes and techniques in the literature of the American Renaissance, with special attention to the writings of Melville, Hawthorne, Emerson, Thoreau and Poe.
ENG733	INDIAN LITERATURE		The course deals with major trends and developments in Indian literature from ancient to modern times. The course will focus primarily on the following topics: the problem of definition; the growth of nationalism; elements of unity in a multilingual situation; ancient religious and secular liteature; impact of Western literatures; modern regional literatures.
ENG735	COMMONWEALTH LITERATURE		The course covers literature in English in the Commonwealth countries of Africa, Australia, Canada, India, New Zealand, and the West Indies. An attempt willbe made to show that common wealth writers, while contributing to the literature of their own country, find their particular artistic understanding inescapably informed by what William Walsh calls other silent but active aims.
ENG735A	COMMONWEALTH LITERATURE		The course covers literature in English in the Commonwealth countries of Africa, Australia, Canada, India, New Zealand, and the West Indies. An attempt willbe made to show that commonwealth writers, while contributing to the literature of their own country, find their particular artistic understanding inescapably informed by what William Walsh calls other silent but active aims.
ENG742A	RESPONSBILE DISSENT		Concept and practice of responsible dissent in various sociopolitical contexts: Notions of dissent and responsible dissent, ethical roots of dissent, contexts and forms of dissent, profiles of dissenties (Chomsky, Russell, early Gandhi, Ram Mohan Roy, King, etc.), role and responsibility of the inttellectual, role of media in supression of facts and dissemination of misinformation, strategies of manufacture of consent in totalitarian and democratic structures.
ENG743	FEMINIST THEORY AND LITERATURE	3-1-0--4	Definitions: the Sex/Gender debate, Masculinity and femininity, patriarchy, the feminism/gender studies

			debate.Gender and Identity: Processes of Identity formation, gender roles in different social contexts, gendered lifescripts and their historical transformations.Gender and Representation: The politics of representation, external vs internal self representations, the media and representation.The Politics of Feminism: The reasons and implications of focusing on genderas a subject of inquiry, the relationship between theory and practice, thelocational specificity of feminism, the role of feminism in India.
ENG743A	FEMINIST THEORY AND LITERATURE		Definitins: The Sex / Gender debaate, Masculinity and femininity, patriarchy, the feminism/ gender studies debate. Gender and Identity: Processes of Identity formation, gender roles ain different social contexts, gendered lifescripts and their historical transformations. Gender and Representation: The politics of representation, external vs internal self representations, the media and representation. The Politics of Feminism: The reasons and implications of focusing on gender as a subject of inquirey, the relationship between theory and practice, the locational specificity of feminism the role of feminism in India.
ENG748	COGNITIVE LINGUISTICS		The course explores language cognition mappings in varied contexts such as unilingual, billingual and sign language use, Cross linguistic variations in basic conceptual domains such as time and apace and lexicalization patterns will be examined. Other topics include nature of linguistic representations open class semantics and semantics of grammar type hierarchies and continuums, compositional structures and cocompositionality, noncompositional structures, constrains on possible grammars, perceptual processes and grounding.
ENG749	POSTMODERN THEORY AND LITERATURE	3-0-0--4	Any postgraduate course in Modern Literature Acquainting the students with the major critical concepts, selfreflexive texts and amorphous themes of Post modernism, the course aims to explore the usefulness of the term postmodernism as a means of approaching contemporary literature. The course will offer an advanced introduction to the central concepts of postmodernism by providing an approach to contemporary American, LatinAmerican, European and Indian (Writing in English) literature. Major topics for discussion are: The relevance of Postmodernism, differences between Modernism and Postmodernism, Deconstruction, the Death of the Author, Rhizome, Knowledge and Power, Entropy, the Literature of Exhaustion, the Hyperreal and the Simulacrum, Cyberspace and Cyberpunk, Postmodern Ethics, Postmodernism and Popular Culture, Postmodernism in an Indian context, Postmodern Films, Postmodernism and its Limitations.

ENG750	POSTWAR AMERICAN FICTION	3-0-0--4	Postwar American fiction is characterized by a complex sensibility that is often pervasive in the novels of the period from 1945 through the Cold War of the seventies and eighties to the present. With America coming into unexampled prosperity following WWII, this sensibility manifests itself as a sense of triumphalism only to give way to introspection and self debate concerning the problematic of defining American identity and nationhood against a distinct multicultural presence, and the unviability of American Dream; in a transnational and globalized world in the creation of which, curiously, America itself hasenormous investments. Interestingly, fiction of this period frames war both asa trope and a realistic concern. The protracted cultural wars which began withthe Civil Rights era of the 1960s infused new life into the literature of the United States in that the traditionally oppressed voices of minorities, be they African Americans, women or the immigrants, began to be heard. And the variegated literary movements (postmodernism, humanism, and feminism toname a few) and fictional strategies (such as protest, fantasy, black humor) employed in the genre bring in to one’s reading a nuanced and engaging perspective of how these writers have negotiated reality into their imaginative artistic vision. The fiction of this period is marked by thematic concerns suchas politics, paranoia, race, money, technology, sex, suburbia, urban decay, immigration, and spirituality, among others. The course strives to close read select texts, in the light of rigorous theoretical interventions.
ENG750A	POSTWAR AMERICAN FICTION	3-0-0-0-9	Postwar American fiction is characterized by a complex sensibility that is often pervasive in the novels of the period from 1945 through the Cold War of the seventies and eighties to the present. With America coming into unexampled prosperity following WWII, this sensibility manifests itself as a sense of triumphalism only to give way to introspection and selfdebate concerning the problematic of defining American identity and nationhood against a distinct multicultural presence, and the unviability of American Dream; in a transnational and globalized world in the creation of which, curiously, America itself has enormous investments. Interestingly, fiction of this period frames war both as a trope and a realistic concern. The protracted cultural wars which began with the Civil Rights era of the 1960s infused new life into the literature of the United States in that the traditionally oppressed voices of minorities, be they African Americans, women or the immigrants, began to be heard. And the variegated literary movements (postmodernism, humanism, and feminism to name a few) and fictional strategies

			(such as protest, fantasy, black humor) employed in the genre bring in to one’s reading a nuanced and engaging perspective of how these writers have negotiated reality into their imaginative artistic vision. The fiction of this period is marked by thematic concerns such as politics, paranoia, race, money, technology, sex, suburbia, urban decay, immigration, and spirituality, among others. The course strives to closeread select texts, in the light of rigorous theoretical interventions.
ENG751	CONTEMPORARY CRITICAL THEORIES & LITERARY PRAXES	3-0-0-0-4	ecocriticism, hypertext theory, and cyber criticism. Siginficant contributions by the following and other such representative figures will be incorporated in the discussions: Edward Said, Frantz Fanon Fredric Jameson, Gilles Deleuze and Felix Guattari, Jacques Derrida, any postgraduate course in English Literature is desirable Contemporary critical theories particularly those of the post 1960s, have problematised the writing, reading and receiving of literature. This course examines complex aspects of recent critrical theories associated with gender, race, subjectivity, sexuality, textuality, narratology, ecology, and notions ofculture and history. It aims to expose students to contemporary theories that would enhance their research into chosen areas of literature. Delving on relevant issues and debates, the course acquaints students with various strategies of reading, interpretation and analysis of literary/nonliterary texts and the acquistion of current critical vocabulary. Important topics of discussion include semiotics, deconstruction, interextuality, reader response theory, autobiographical theory, post Lacanian psychoanalytic criticism, postcolonialism, postmodernism, third wave feminism, cultural materialism, new historicism, posthumanism Mikhail Bakhtin, Michel Foucault, Roland Barthes, Stephen Greenblatt and Umberto Eco.
ENG751A	CONTEMPORARY CRITICAL THEORIES & LITERARY PRAXES	3-0-0-0-9	Contemporary critical theories particularly those of the post 1960’s, have problematised the writing, rading and receiving of leterature. This course examines complex aspects of recent critical theories associated with gender, race, subjectivity, sexuality, textuality, narratology, ecology, and notions of culture and history. It aims to expose students to contemporary theories that would enhance their research into chosen areas of literature. Delving on relevant issues and debates, the course acquaints students with various strategies of reading, interpretation and analysis of literary/nonliterary texts and the acquisition of current critical vocabulary. Important topics of discussion include semiotics, deconstruction, interextuality, reader response theory, autobiographical theory, post Lacanian psychoanalytic criticism, postcolonialism,

			postmodernism, third wave feminism, cultural materialism, new histricism, posthumanism,
ENG752	COMPARATIVE AESTHETICS	3-0-0-0-4	The course explores the convergence and divergence of eastern and western aesthetic practices, in an attempt to two. Its scope includes classical Greekand Sanskrit texts like Bharata's Natyasastra and Aristotles Poetics which are extensive treatises on dramaturgy, Longinus's concept of the sublime, Anandavardhanas concept of dhvani and postulates of New Criticism.
ENG752A	COMPARATIVE AESTHETICS	3-0-0-0-9	The course explores the convergence and divergence of eastern and western aesthetic practices, in an attempt to two. Its scope includes classical Greekand Sanskrit texts like Bharata's Natyasastra and Aristotles Poetics which areextensive treatises on dramaturgy, Longinus s concept of the sublime, Anandavardhanas concept of dhvani and postulates of New Criticism.
ENG753	TRANSLATION STUDIES	3-0-0-0-4	The course covers the theoretical aspect of the practice of translation in the west and in India. It includes the history of translation and various forms of translation like retellings and intersemiotic adaptations. The course also explores the cultural turn in translation including aspects like the politics implicit in the practice of translation between unequal languages in a globalized world.
ENG754	HISTORICAL LINGUISTICS	3-0-0-0-4	This subject is an introduction to historical linguistics, the study of language change and linguistic relationships. We will explore the kinds of changes that languages undergo throughout their history, drawing on material from a wide range of languages. The comparative method of linguistic reconstruction will be introduced and demonstrated, together with methods of language classification and subgrouping. We will also investigate language change in progress and relations between language andcultural history. Topics to be discussed: Introduction to what is historical linguistics? Lexical and semantic change, borrowing Phonological change, Morphological change, Syntactic change, Language classification, subgrouping and regrouping, Linguistic reconstruction: comparative and other methods Models of language change, Language change in progress, Language and cultural history Language and prehistory, long distance comparisons. **Course Reference**:1. Campbell, Lyle 1998. Historical Linguistics: An Introduction. Edinburgh University PressMillar, Robert McColl (ed.) 2007; 2. Trasks Historical Linguistics. Hodder Arnold Bhat, D.N.S. 2001; 3. Sound Change. MLBD.Croft, William 2000. Explaining Language Change: An Evolutionary Approach. Longman. Crowley, Terry 2010; 4. An Introduction to Historical Linguistics. Oxford

			University Press.Crystal, David 2002; 5. The English Language. Penguin Durie, Mark and Malcolm Ross 1996; 6. The Comparative Method Reviewed: Regularity and Irregularity in Language Change. Oxford University Press [D&R below] Fortson, Benjamin W. 2004; 7. Indo European Language and Culture. Blackwell.Hock, Hans Henrich 1991; 8. Principles of Historical Linguistics. Mouton de GruyterJoseph, Brian D. and Richard D. Janda 2003. The Handbook of Historical Linguistics. Blackwell Lightfoot, D.W. 1979; 9. Principles of Diachronic Syntax. CUPMcMahon, April S. 1994; 10. Understanding Language Change. CUP Schendl, Herbert 2001. Historical Linguistics. Oxford University Press
ENG799	PHD THESIS	----	Ph. D. Thesis
HSS401A	SOFT SKILLS AND PERSONALITY DEVELOPMENT	3-0-0-0-9	Personal Skills: Self Assessment; Identifying Strength & Limitations; Habits, Will Power and Drives; Developing Self Esteem and Building Self Confidence, Significance of Self Discipline. Understanding Perceptions, Attitudes, and Personality Types. MindSet: Growth and Fixed; Values and Beliefs. Motivation and Achieving Excellence; Self Actualisation Need. Goal Setting, Life and Career Planning; Constructive Thinking. Professional Skills: Communicating Clearly: Understanding and Overcoming barriers; Cross gender/Cross Cultural communication, Strategic Communication. Active Listening. Persuasive Speaking and Presentation Skills. Conducting Meetings, Writing Minutes, Sending Memos and Notices. Netiquette: Effective Email Communication; Telephone Etiquette. Body Language in Group Discussion and Interview. Interpersonal Skills: Enhancing Empathy, Showing Sympathy and Dealing with Antipathy; Gaining Trust and Developing Emotional Bonding. Ethics and Etiquettes (Social and Official Settings); Respecting Privacy; Civic Sense and Care for the Environment. Negotiating, Decision Making, Conflict Resolution, Five Styles. Emotional Literacy; Assertiveness versus Aggressiveness; Learning to Say No.; Learning to Appreciate and Give Praise; Presenting Bad News. Humour, Jokes and Anecdotes in Effective Communication. Management Skills: Managing Time and Beating Procrastination. Managing People: Leading and Working with Team (Coordination and Cooperation); Developing Accountability, Commitment and Responsibility; Behaving Conscientiously. Managing Stress and Maintaining Positive Outlook. Managing Health, Boosting Memory, Enhancing Study Skills. Managing Money and Love; Balancing Personal and Professional Life. Dorch, Patricia. **Course Reference**:1.What Are Soft Skills? New

			York: Execu Dress Publisher, 2013.Kamin, Maxine. Soft Skills Revolution: A Guide for Connecting with Compassion for Trainers, Teams, and Leaders. Washington, DC: Pfeiffer & Company, 2013; 2. Klaus, Peggy, Jane Rohman & Molly Hamaker. The Hard Truth about Soft Skills. London: HarperCollins Ebooks, 2007; 3. Petes S. J., Francis.Soft Skills and Professional Communication. New Delhi: Tata McGrawHill Education, 2011; 4. Stein, Steven J. & Howard E. Book. The EQ Edge: Emotional Intelligence and Your Success. Canada: Wiley & Sons, 2006.
HSS403	SOCIAL AND BEHAVIOURAL ASPECTS OF HEALTH	3-1-0-0-4	From biomedical model of health to sociopsychological model of health; Illness cognition; Social processes, illness and coping; Methodological issues in study of health; Stigma aod testing and treatment seeking behavior; Health policy in India; Preventive, curative and palliative health care; Role of NGOs aod CBOs.
HSS403A	SOCIAL & BEHAVIOURAL ASPECTS OF HEALTH	3-0-0-0-9	From biomedical model of health to sociopsychological model of health; Illness cognition; Social processes, illness and coping; Methodological issues in study of health; Stigma aod testing and treatment seeking behavior; Health policy in India; Preventive, curative and palliative health care; Role of NGOs aod CBOs.
HSS701	THEORIES OF RIGHTS	3-0-0--4	The aim of the course is to understand the origins of the notions in the classical period, its rejuvenation in the medieval and early modern periods, and contemporary debates surrounding different theories of rights with special emphasis on examining debates on human rights. Some specific domains of rights will be taken up for intensive study in the light of various theoretical positions. Themes include: Stoicism, Republicanism, Natural Law Discourse, Liberalism, Utilitiarianism, Legal Positivism, Marxism, and Communitarianism.
HSS702	HEALTH AND ILLNES: PSYCHO-SOCIAL PERSPECTIVES	3-0-0-0-4	1.Health and illness: biomedical and sociopsychological models; 2.Social cognitive models of health; 3.Culture and health; cross cultural and comparative research in mental health; 4.Illness, distress and self; 5.Self regulation of health and illness; illness cognition; 6.Positivist, feminist and materialist approaches to health; 7.Stress and coping; 8.Personal and social meanings of illness; Illness narratives and cultural construction of illness; 9.Postmodernity, health policy and its impact on peoples health; 10.Major national, regional and ethnographic studies on physical and mental health in India; 11.Positivist, qualitative, and ethnographic approaches; 12.National health policy in India and issues for research; Caregiving in the Indian context The main readings are various journal articles and

			survey reports and policy documents that are available online. **Course Reference**: 1. Margaret Konz Snooks, Health Psychology: Biological, Psychological, and Sociocultural Perspectives; 2. Bernice A. Pescosolido et al. (eds.), Handbook of the Sociology of Health, Illness, and Healing: A Blueprint for the 21st Century; 3. K. Charmaz and D. A. Paterniti, Health. Illness and Healing Social Context and Self; 4. David Wainwright (ed.), A Sociology of Health; 5. Poul Rohleder, Critical Issues in Clinical & Health Psychology; 6. John Germov (ed.), Second Opinion; 7. Sarah Nettleton, The Sociology of Health and Illness; 8. L. D. Cameron and H. Leventhal, The Selfregulation of Health and Illness Behaviour; 9. A. Kleinman, The illness narratives: Suffering, healing and the human condition.
HSS702A	HEALTH AND ILLNES: PSYCHO-SOCIAL PERSPECTIVES	3-0-0-0-9	1.Health and illness: biomedical and sociopsychological models; 2.Social cognitive models of health; 3.Culture and health; cross cultural and comparative research in mental health; 4.Illness, distress and self; 5.Self regulation of health and illness; illness cognition; 6.Positivist, feminist and materialist approaches to health; 7.Stress and coping; 8.Personal and social meanings of illness; Illness narratives and cultural construction of illness; 9.Postmodernity, health policy and its impact on peoples health; 10.Major national, regional and ethnographic studies on physical and mental health in India; 11.Positivist, qualitative, and ethnographic approaches; 12.National health policy in India and issues for research; Caregiving in the Indian context The main readings are various journal articles and survey reports and policy documents that are available online. **Course Reference**: 1. Margaret Konz Snooks, Health Psychology: Biological, Psychological, and Sociocultural Perspectives; 2. Bernice A. Pescosolido et al. (eds.), Handbook of the Sociology of Health, Illness, and Healing: A Blueprint for the 21st Century; 3. K. Charmaz and D. A. Paterniti, Health. Illness and Healing Social Context and Self; 4. David Wainwright (ed.), A Sociology of Health; 5. Poul Rohleder, Critical Issues in Clinical & Health Psychology; 6. John Germov (ed.), Second Opinion; 7. Sarah Nettleton, The Sociology of Health and Illness; 8. L. D. Cameron and H. Leventhal, The Selfregulation of Health and Illness Behaviour; 9. A. Kleinman, The illness narratives: Suffering, healing and the human condition.
PHI140	INTRODUCTION TO INDIAN PHILOSOPHY	3-0-0-0-4	1. Introduction: The Dialectical Style of Indian Philosophy. The Khandana Mandana style. Stating the real and imaginary objections. Refutation of Objections. Establishing the position; .2. Historical

			Sketch: The AstikaNastika division and its logic. TheCriteria of Categorization; 3. Valid Cognition (prama): Its definition in different schools (at leastin Nyaya, Bauddha, Mimamsa and Advaita). Genesis and categorization ofvalid cognition in different schools; 4. Content of Valid cognition (prameya): That which is there Indian Metaphysics. Indian Realism (Nyaya). Indian Idealism (Buddhism and Advaita); 5. Causality: Causal theories in different schools (Adhityasamutpada, Arambhavada, Parinamavada, Vivartavada and Pratityasamutpada); 6. Logic: Inference (anumana) and its features in Nyaya. Logical Blockersor Hetvabhasas in Nyaya; 7. Ethics: Theory of karman as an extension ofIndian causal theory. Purushartha. **Course Reference**: 1. Six Ways of Knowing, D M Datta, Calcutta University, 1972; 2. An Introduction to Indian Philosophy, S Chatterjee and D Datta, Rupa & Co., 2007 (paperback); 3. Outlines of Indian Philosophy, M Hiriyanna, Motilal Banarasidass, 1999 (paperback); 4. A Critical Survey ofIndian Philosophy, C D Sharma, Motilal Banarasidass, 1987; 5. The Philosophical Traditions ofIndia, P T Raju, Motilal Banarasidass, 1992; 6. A History of Indian Philosophy, S N Dasgupta, Cambridge University Press, 1922; 7. Encyclopedia ofIndian Philosophy,Voll 12, ed. Karl Potter, Motilal Banarasidass.
PHI140A	INTRODUCTION TO INDIAN PHILOSOPHY	3-1-0-0-11	1. Introduction: The Dialectical Style of Indian Philosophy the Khandana Mandana style. Stating the real and imaginary objections. Refutation of Objections. Establishing the position; 2. Historical Sketch: The AstikaNastika division and its logic. TheCriteria of Categorization; 3. Valid Cognition (prama): Its definition in different schools (at leastin Nyaya, Bauddha, Mimamsa and Advaita). Genesis and categorization ofvalid cognition in different schools; 4. Content of Valid cognition (prameya): That which is thereIndianMetaphysics. Indian Realism (Nyaya). Indian Idealism (Buddhism andAdvaita); 5. Causality: Causal theories in different schools (Adhityasamutpada, Arambhavada, Parinamavada, Vivartavada and Pratityasamutpada); 6. Logic: Inference (anumana) and its features in Nyaya. Logical Blockersor Hetvabhasas in Nyaya; 7. Ethics: Theory of karman as an extension of Indian causal theory. Purushartha. **Course Reference**: 1.Six Ways of Knowing, D M Datta, Calcutta University, 1972; 2. An Introduction to Indian Philosophy, S Chatterjee and D Datta, Rupa & Co., 2007(paperback); 3. Outlines of Indian Philosophy, M Hiriyanna, Motilal Banarasidass, 1999 (paperback); 4. A Critical Survey of Indian Philosophy, C D Sharma, Motilal Banarasidass, 1987;

			5. The Philosophical Traditions ofIndia, P T Raju, Motilal Banarasidass, 1992; 6. A History of Indian Philosophy, S N Dasgupta, Cambridge University Press, 1922; 7. Encyclopedia of Indian Philosophy,Voll 12, ed. Karl Potter, Motilal Banarasidass,
PHI141	INTRODUCTION TO PHILOSOPHY	3-1-0--4	General introduction to philosophy: Nature of philosophy; its relations with, and differences from, science, religion, art, and culture. Metaphysics: Causality; determinism and free will Materialism and Idealism. Personal Identity_ Critique of Metaphysics. Logic: Truth, validity, and arguments. Epistemology: Scepticism; Defining knowledge; The Gettier problem. Theories of perception. Descartes and foundationalism. Coherentism. Naturalized epistemology Ethics: Utilitarianism. Kant. Virtue ethics. Applied Ethics: Some problems of applied ethics. Chisholm, Roderick. **Course Reference**: 1. Theory of Knowledge. Prentice Hall, Englewood Cliffs NJ, 1989.Horner, Chris and Emrys Westacott; 2. Thinking through Philosophy. Cambridge University Press, Cambridge, 2000.Russell, Bertrand. Problems of Philosophy. Oxford University Press, 1912, Reprint 1972; 3. Singer, Peter. Practical Ethics. 2nd edn. Cambridge University Press, Cambridge, 1993.
PHI141A	INTRODUCTION TO PHILOSOPHY	3-1-0-0-11	General introduction to philosophy: Nature of philosophy; its relations with, and differences from, science, religion, art, and culture. Metaphysics: Causality; determinism and free will Materialism and Idealism. Personal Identity_Critique of Metaphysics. Logic: Truth, validity, and arguments. Epistemology: Scepticism; Defining knowledge; The Gettier problem. Theories of perception. Descartes and foundationalism. Coherentism. Naturalized epistemology. Ethics: Utilitarianism. Kant. Virtue ethics. Applied Ethics: Some problems of applied ethics. Chisholm, Roderick. **Course Reference**: 1. Theory of Knowledge. Prentice Hall, Englewood Cliffs NJ, 1989. Horner, Chris and Emrys Westacott; 2. Thinking through Philosophy. Cambridge University Press, Cambridge, 2000. Russell, Bertrand. Problems of Philosophy. Oxford University Press, 1912, Reprint 1972; 3. Singer, Peter. Practical Ethics. 2nd edn. Cambridge University Press, Cambridge, 1993.
PHI141B	INTRODUCTION TO PHILOSOPHY	3-1-0-0-11	General Introduction to the Course; Nature of Knowledge; Sources of Knowledge; the Problem of Perception; Skepticism; Kinds of Metaphysics; Metaphysical Systems; MindBody Dualism; Proofs for the Existence of God; Positivistic Critique of Metaphysics; Normative Ethics; Meta Ethics; Free will and Moral responsibility.

PHI142	INTRODUCTION TO LOGIC	3-1-0--4	Introduction: Logic as the science of distinguishing valid arguments from invalid ones. Fallacies. Aristotelian Logic and its limitations Propositional Logic: Propositional Calculus. Logical Operators. Translation from Natural Language Arguments. Relations between Logical Connectives. Rules of Deduction. TruthTables. Test of Invalidity. Semantic Tableaux Method Predicate Logic: Predicate Calculus. Quantifiers and Properties. Translations. Bondage andFreedom. Rules of Deduction (Generalization and Instantiation) and Constraints. Testing Invalidity in Nonrelational Predicate Calculus using the Truth Table Method. Semantic Tableaux Method Axiomatic System: Introduction to the System of Principia Mathematica. Godel's Incompleteness Theorem. **Course Reference**: 1. Copi, Irvin and Carl Cohen, Introduction to Logic, Prentice Hall, New Jeresy, 101h edn., 1998; 2.Hausman, Alan, Howard Kahane, and Paul Tidman, Logic and Philosophy: A Modern Introduction, Wadsworth Publishing, Boston, 2010; 3.Hurley, Patrick, Concise Introduction to Logic, Wadsworth Publishing, Boston, 2007; 4.Kalish, Donais and Richard Montague, Logic: Techniques of Formal Reasoning, Harcourt, Brace & World, Inc., 1964; 5.Crossley, John, et al, What is Mathematical Logic, Oxford University Press, Oxford, 1972; 6.Gardner, Martin, Aha! Insight, Aha! Gotcha, The Mathematical Association of America, 2002; 7. Hedman, Shawn, First course in Mathematical Logic, Oxford University Press, Oxford, 2004, pp1115.
PHI142A	INTRODUCTION TO LOGIC	3-1-0-0-11	Introduction: Logic as the science of distinguishing valid arguments from invalid ones. Fallacies. Aristotelian Logic and its limitations Propositional Logic: Propositional Calculus. Logical Operators. Translation from Natural Language Arguments. Relations between Logical Connectives. Rules of Deduction. TruthTables. Test of Invalidity. Semantic Tableaux Method Predicate Logic: Predicate Calculus. Quantifiers and Properties. Translations. Bondage andFreedom. Rules of Deduction (Generalization and Instantiation) and Constraints. TestingInvalidity in Nonrelational Predicate Calculus using the Truth Table Method. SemanticTableaux Method Axiomatic System: Introduction to the System of Principia Mathematica. Godel's Incompleteness Theorem. **Course Reference**: 1.Copi, Irvin and Carl Cohen, Introduction to Logic, Prentice Hall, New Jeresy, 101h edn., 1998; 2. Hausman, Alan, Howard Kahane, and Paul Tidman, Logic and Philosophy: A Modern Introduction, Wadsworth Publishing, Boston, 2010; 3. Hurley, Patrick, Concise Introduction to Logic, Wadsworth Publishing, Boston, 2007; 4. Kalish,

			Donais and Richard Montague, Logic: Techniques of Formal Reasoning, Harcourt, Brace & World, Inc., 1964; 5.Crossley, John, et al, What is Mathematical Logic, Oxford University Press, Oxford, 1972; 6.Gardner, Martin, Aha! Insight, Aha! Gotcha, The Mathematical Association of America, 2002; 7. Hedman, Shawn, First course in Mathematical Logic, Oxford University Press, Oxford, 2004, pp1115
PHI442	MARXISM, GANDHI AND EXISTENTIALISM	3-1-0--4	This course deals with the philosophical ideas of Karl Marx, Gandhi and someof the important existentialist thinkers, especially JeanPaul Sartre and Matrin Heideggar. Major emphasis is laid on the moral issues raised by these thinkers.
PHI442A	MARXISM, GANDHI AND EXISTENTIALISM	3-0-0-0-9	This course deals with the philosophical ideas of Karl Marx, Gandhi and someof the important existentialist thinkers, especially JeanPaul Sartre and Matrin Heideggar. Major emphasis is laid on the moral issues raised by these thinkers.
PHI446	PHILOSOPHY OF SCIENCE	3-0-0-0-4	On what Philosophy of Science is; Logic and Empiricism; Theory and Observation; Evidence Confirmation and Falsificationism; Induction and Probability; Scientific Revolution versus Normal Science; Scientific Explanation I: Theoretical Entities; Scientific Explanation II: Naturalism, Realism and Antirealism; Laws of Nature, dispositions and causes and Conditionals, Causality and Indeterminism, Bayesian and Modern theories of Evidence; Science and Values. **Course Reference**: 1. Peter Godfrey Smith (2003), Theory and Reality: An Introduction to Philosophy of Science, University of Chicago Press. [Standard Text for this course] James Ladyman (2002); 2. Understanding Philosophy of Science, Routledge, London. Hacking, I. (1983); 3. Representing and Intervening, Cambridge University Press, Cambridge. Chalmers, A. F. (1982); 4. What Is This Thing Called Science? Open University Press, Milton Keynes, second edition. Thomas Kuhn (! 996) The Structure of Scientific Revolutions, University of Chicago Press. Okasha Samir (2002); 5. Short introduction to philosophy of science, Oxford: Oxford University Press. Hempel, Carl (I 966), Philosophy of natural science, PrenticeHall foundations of philosophy series. Englewood Cliffs, N.J: PrenticeHall. Gillies, D. A. (1993); 6. Philosophy of Science in the Twentieth Century: Four CentralThemes, Blackwell Publishers. Rom Harre (1972); 7. The philosophies of Science: An introductory survey, Oxford University press, USA.
PHI446A	PHILOSOPHY OF SCIENCE	3-0-0-0-9	On what Philosophy of Science is; Logic and Empiricism; Theory and Observation; Evidence, Confirmation and Falsificationism; Induction and Probability; Scientific Revolution versus Normal Science; Scientific Explanation-I: Theoretical Entities;

			Scientific Explanation-II: Naturalism, Realism and Antirealism; Laws of Nature, dispositions and causes and Conditionals, Causality and Indeterminism, Bayesian and Modern theories of Evidence; Science and Values. **Course Reference**: 1. Peter Godfrey Smith (2003), Theory and Reality: An Introduction to Philosophy of Science, University of Chicago Press. [Standard Text for this course]; 2. James Ladyman (2002), Understanding Philosophy of Science, Routledge, London. Hacking, I. (1983); 3. Representing and Intervening, Cambridge University Press, Cambridge. Chalmers, A. F. (1982); 4. What Is This Thing Called Science? Open University Press, Milton Keynes, second edition. Thomas Kuhn (1996) The Structure of Scientific Revolutions, University of Chicago Press. Okasha Samir (2002); 5. Short introduction to philosophy of science, Oxford: Oxford University Press. Hempel, Carl (I 966), Philosophy of natural science, Prentice Hall foundations of philosophyseries. Englewood Cliffs, N.J: Prentice Hall. Gillies, D. A (1993); 6. Philosophy of Science in the Twentieth Century: Four Central Themes, Blackwell Publishers. Rom Harre (1972); 7. The philosophies of Science: An introductory survey, Oxford University press, USA.
PHI447	MORAL THINKING	3-1-0--4	Introduction to Ethical Theories (Consequentialist and Nonconsequentialist theories, Hedonism, Utilitarianism, Deontological theories, Ethical Rules, Situation Ethics, Virtue Ethics). Metaethical Theories (Ethical Relativism: Is Anything Wrong at all? Ethical Naturalism, Nonnaturalism, Noncognitive Theories, Intuitionism, Approach to an Adequate Theory; the Moralpoint of view; Why be Moral?). Ethics in the Indian tradition. Applied Ethics: Issues and Dilemmas. **Course Reference**: 1. Frankena, W.K. Ethics. New Delhi: Prentice Hall of India,1999; 2. Hospers, John. An Introduction to Philosophical Analysis. New Delhi: Allied Publishers,1967; 3. LaFollette, Hugh, ed. Ethics in Practice: An Anthology. Cambridge: Blackwell,1997; 4. Radhakrishnan'S. Indian Philosophy. 2 Vols. New Delhi: Oxford University Press, 1940; 5. Pojman, Louis (Ed.) Ethical Theory: Classical and Contemporary Readings, Belmont: Wadsworth, 1998; 6. Cahn, Steven M. & Peter Markie (Eds.) Ethics: History. Theory and ContemporaryIssues, Issues, New York: OUP, 1998
PHI447A	MORAL THINKING	3-0-0-0-9	Introduction to Ethical Theories (Consequentialist and Nonconsequentialist theories, Hedonism, Utilitarianism, Deontological theories, Ethical Rules, Situation Ethics, Virtue Ethics). Metaethical Theories (Ethical Relativism: Is Anything Wrong at all? Ethical Naturalism, Nonnaturalism, Noncognitive Theories,

			Intuitionism, Approach to an Adequate Theory; the Moral point of view; Why be Moral?). Ethics in the Indian tradition. Applied Ethics: Issues and Dilemmas. **Course Reference**: 1. Frankena, W.K. Ethics. New Delhi: Prentice Hall ofindia,1999; 2. Hospers, John. An Introduction to Philosophical Analysis. New Delhi: Allied Publishers,1967; 3. LaFollette, Hugh, ed. Ethics in Practice: An Anthology. Cambridge: Blackwell,1997; 4. Radhakrishnan, S. Indian Philosophy. 2 Vols. New Delhi: Oxford University Press, 1940; 5. Pojman, Louis (Ed.) Ethical Theory: Classical and Contemporary Readings, Belmont: Wadsworth, 1998; 6. Cahn, Steven M. & Peter Markie (Eds.) Ethics: History. Theory and Contemporary Issues, Issues, New York: OUP, 1998.
PHI448	INDIVIDUAL VS AUTHORITY	3-0-0-0-4	The distinction between Authority, Power and Sovereignty; Political forms of Authority; The individuals Rights and his Legitimate Autonomy; Encroachment on the Individuals Legtimate Sphere: its Sources and their Disguised Forms; Misuse of Power and Safeguards against it.
PHI448A	INDIVIDUAL VS AUTHORITY	3-0-0-0-9	The distinction between Authority, Power and Sovereignty; Political forms of Authority; The individuals Rights and his Legitimate Autonomy; Encroachment on the Individuals Legtimate Sphere: its Sources and their Disguised Forms; Misuse of Power and Safeguards against it.
PHI450	PHILOSOPHICAL AESTHETICS	3-0-0--4	The Aesthetic attitude; Aesthetic Experience; Art and Aesthetic; Defining Artand its Problems; Art and Emotion; Literary Aesthetics; Art, Society and Morality; Philosophy of Literature.
PHI450A	PHILOSOPHICAL AESTHETICS	3-0-0-0-9	The Aesthetic attitude; Aesthetic Experience; Art and Aesthetic; Defining Artand its Problems; Art and Emotion; Literary Aesthetics; Art, Society and Morality; Philosophy of Literature.
PHI451	TOPICS IN INDIAN PHILOSOPHY	3-1-0--4	Introduction and Historical Sketch; Comparative Ontology: Object of knowledge (prameya); Irreducible ontological categories (padarthas) in different schools; Different theories of error (khyativada); Theories on Causation (karanata); Comparative Epistemology: Cognition; Definitions of valid cognition (prama); Means of valid cognitions: Definition and number (indifferent schools); Logic: Nyaya Logic and theory of Inference; Logical fallacies; Nyayadoctrine on formal representation of cognitions. Datta, D. M. Six Ways of Knowing. Calcutta: **Course Reference**: 1. Calcutta University. 1972, Chatterjee, S. and D. Datta. An Introduction to Indian Philosophy. Calcutta: Rupa & Co. 2007; 2. Chatterjee, S. C. Nyaya theory of knowledge. Bharatiya Kala Prakashan. 2008; 3. Bhattacharya, G. Tarkasamgrahadipika on Tarkasamgraha.

			Progressive Publishers. 2008; 4. Dasgupta, S. N. A History of Indian Philosophy. Cambridge University Press. 1922; 5. Potter, K. (ed). Encyclopedia of Indian Philosophy. New Delhi: Motilal Banarasidass.
PHI451A	TOPICS IN INDIAN PHILOSOPHY	3-0-0-0-9	Introduction and Historical Sketch; Comparative Ontology: Object of knowledge (prameya); Irreducible ontological categories (padarthas) in different schools; Different theories of error(khyativada); Theories on Causation (karanata); Comparative Epistemology: Cognition; Definitions of valid cognition (prama); Means of valid cognitions: Definition and number (indifferent schools); Logic: Nyaya Logic and theory of Inference; Logical fallacies; Nyayadoctrine on formal representation of cognitions. Datta, D. M. Six Ways of Knowing. **Course Reference**: 1. Calcutta: Calcutta University. 1972; Chatterjee, S. and D. Datta. An Introduction to Indian Philosophy. Calcutta: Rupa & Co. 2007; 2. Chatterjee, S. C. Nyaya theory of knowledge. Bharatiya Kala Prakashan. 2008; 3. Bhattacharya, G. Tarkasamgrahadipika on Tarkasamgraha. Progressive Publishers. 2008; 4. Dasgupta, S. N. A History of Indian Philosophy. Cambridge University Press. 1922; 5. Potter, K. (ed). Encyclopedia of Indian Philosophy. New Delhi: Motilal Banarasidass.
PHI455	PHILOSOPHICAL LOGIC	3-0-0-0-4	Brief overview of first order logic, Problem of Logical Consequence, Deviant Logics: Many valued Logic I: Three valued Logics, Many Valued Logic 2: Many valued logic and Degrees of truth, Para consistent Logic, Basic concepts of Fuzzy Logic; Extensions of First order Logic: Basic concepts of Normal Modal Logic, Epistemic Logic, Problem of Counter factuals; Logical Pluralism **Course Reference**: 1. James Graham Priest, An Introduction to NonClassical Logic, Cambridge: CambridgeUniversity Press 2001 (standard Text for the course); 2. Colin Mcginn, Logical Properties, Oxford University Press, 2000; 3. John P. Burgess, Philosophical Logic, Princeton University Press, 2009; 4. Quine, W. V. 0, Philosophy of Logic, Prentice Hall, 1970; 5. Haack, Susan, Deviant Logic, Cambridge University Press, 1974; 6. Jacquette, Dale. Philosophy of Logic. Amsterdam, The Netherlands: Elsevier/NorthHolland, 2007; 7. Rescher, Nicholas. Topics in Philosophical Logic. Dordrecht: D. Reidel, 1968; 8. Blackburn, Patrick, Maarten de Rijke, and Y de Venema. Modal Logic. Cambridge [England]: Cambridge University Press, 2001; 9. Lewis, David K. Counter factuals. Cambridge, Harvard University Press, 1973;10. S. Read, Thinking about Logic, Oxford University Press, 1995; 11. J. C. Beall, Greg Restall, Logical Pluralism, Clarendon Press, 2006.

PHI455A	PHILOSOPHICAL LOGIC	3-0-0-0-9	Brief overview of first order logic, Problem of Logical Consequence, Deviant Logics: Manyvalued Logic I: Three valued Logics, Many Valued Logic 2: Many valued logic and Degrees oftruth, Para consistent Logic, Basic concepts of Fuzzy Logic; Extensions of First order Logic: Basic concepts of Normal Modal Logic, Epistemic Logic, Problem of Counterfactuals; Logical Pluralism **Course Reference**: 1. James Graham Priest, An Introduction to NonClassical Logic, Cambridge: CambridgeUniversity Press 2001 (standard Text for the course); 2. Colin Mcginn, Logical Properties, Oxford University Press, 2000; 3. John P. Burgess, Philosophical Logic, Princeton University Press, 2009; 4. Quine, W. V. 0, Philosophy of Logic, Prentice Hall, 1970; 5. Haack, Susan, Deviant Logic, Cambridge University Press, 1974; 6. Jacquette, Dale. Philosophy of Logic. Amsterdam, The Netherlands: Elsevier/NorthHolland, 2007;7. Rescher, Nicholas. Topics in Philosophical Logic. Dordrecht: D. Reidel, 1968; 8. Blackburn, Patrick, Maarten de Rijke, and Y de Venema. Modal Logic. Cambridge [England]: Cambridge University Press, 2001; 9. Lewis, David K. Counter factuals. Cambridge, Harvard University Press, 1973; 10. S. Read, Thinking about Logic, Oxford University Press, 1995; 11. J. C. Beall, Greg Restall, Logical Pluralism, Clarendon Press, 2006.
PHI751	TWENTIETH CENTURY PHILOSOPHY-I	3-0-0-0-4	An analytical study of Russells The Philosophy of Logical Atomism and Wittgensteins Tractatus Logico Philosophicus: Facts and Propositions; Namesand Objects; Definite Description; Picture Theory of Meaning; Limits ofLanguage, Thought and The World; Silence and the Transcendental. 21-jul-2014
PHI751A	TWENTIETH CENTURY PHILOSOPHY-I	3-0-0-0-9	An analytical study of Russells The Philosophy of Logical Atomism and Wittgensteins Tractatus Logico Philosophicus: Facts and Propositions; Namesand Objects; Definite Description; Picture Theory of Meaning; Limits of Language, Thought and The World; Silence and the Transcendental.
PHI752	PROBLEMS IN PHILOSOPHICAL AESTHETICS	3-0-0--4	Theories of Art as Mimesis, Expression and Form; Aesthetic Experience; Artas a Cultural System; Art and Morality; the Philosophy of Literature: Truth, Meaning, Interpretation and Evaluation; Literature and Cultural Studies.
PHI753	MODERN LOGIC	3-0-0--4	Propositional Logic; Decision Procedures; Quantification Theory; Axiomatic Method; Philosophical Problems.
PHI757	MORAL JUDGEMENT	3-0-0--4	The details of the studies in this course will be designed for advanced studentsdepending on their fields of research.
PHI757A	MORAL JUDGEMENT	3-0-0-0-9	The details of the studies in this course will be designed for advanced students depending on their

			fields of research.
PHI765	TWENTIETH CENTURY PHILOSOPHY II	3-0-0--4	An Analytical Study of the Logic of Ordinary Language; Problems of Meaning, Reference and Truth; the Analytic Synthetic Distinction; the Scheme Content Distinction; Anti foundationalism and Neopragmatism. Special reference to theviews of Wittgenstein, Austin, Strawson, Quine, Davidson, Kripke, Putnam and Thomas Nagel.
PHI765A	TWENTIETH CENTURY PHILOSOPHY II	3-0-0-0-9	An Analytical Study of the Logic of Ordinary Language; Problems of Meaning, Reference and Truth; the Analytic Synthetic Distinction; the Scheme Content Distinction; Antifoundationalism and Neopragmatism. Special reference to the views of Wittgenstein, Austin, Strawson, Quine, Davidson, Kripke, Putnam and Thomas Nagel.
PHI768	MODAL LOGIC	4-0-0--4	The History of Modal notions; The Lewis systems; Strict Implication and Entaliment; The System E and Relevance Logic; Philosophical Problems.
PHI768A	MODAL LOGIC	3-0-0-0-9	The History of Modal notions; The Lewis systems; Strict Implication and Entaliment; The System E and Relevance Logic; Philosophical Problems.
PHI769	INDIAN PHILOSOPHY I	4-0-1--4	A discussion of Epistemological, Metaphysical and Value problems raised in the Classical Systems of Indian Philosophy. Depending on the student's interest, aptitude and progress, either some texts will be studied in details or one set of problems will be studied through relevant texts.
PHI774	SOCIAL AND POLITICAL PHILOSPHY	3-0-0--4	Nature and Method of Social Philosophy; Nature of Society; Theories of Originsof Society; Place and Role of Social Institutions; Social Values and Ends of Political Authority; Sources of Justification and Legitimacy of Political Authority; Individual and Society; Individual and State.
PHI774A	SOCIAL AND POLITICAL PHILOSPHY	3-0-0-0-9	Nature and Method of Social Philosophy; Nature of Society; Theories of Origins of Society; Place and Role of Social Institutions; Social Values and Ends of Political Authority; Sources of Justification and Legitimacy of Political Authority; Individual and Society; Individual and State.
PHI782	EXISTENTIALISM	3-0-0--4	The course seeks to go into the sources of modern existentialist movement in the thoughts of Hegel, Husserl and Kierkegaard. A detailed study of Sartres philosophy will be undertaken in the light of his early and later writings.
PHI782A	EXISTENTIALISM	3-0-0-0-9	The course seeks to go into the sources of modern existentialist movement in the thoughts of Hegel, Husserl and Kierkegaard. A detailed study of Sartre's phiilosophy will be undertaken in the lisght of his early and later writings.
PHI799	PHD THESIS	----	Ph. D. Thesis
PSY151	INTRODUCTION TO	3-1-0--4	Psychological Perspectives and Approaches;

	PSYCHOLOGY		Perception; Learning; Memory; Higher Cognitive Processes; Motivation and Emotion; Intelligence; Personality; Individual Differences.
PSY151A	INTRODUCTION TO PSYCHOLOGY	3-1-0-0-11	Psychological Perspectives and Approaches; Perception; Learning; Memory; Higher Cognitive Processes; Motivation and Emotion; Intelligence; Personality; Individual Differences.
PSY151B	INTRODUCTION TO PSYCHOLOGY	3-1-0-0-11	Psychological Perspectives and Approaches; Perception; Learning; Memory; Higher Cognitive Processes; Motivation and Emotion; Intelligence; Personality; Individual Differences.
PSY152	APPLICATION OF PSYCHOLOGY TO LIFE	3-1-0-0-4	Nature and Scope of Applied Psychology, Historical Perspective, Areas of Applied Psychology, Roles and Skills of Applied Psychologists, Ethical Issues, Clinical and Counseling Psychology, Community Psychology and Mental Health, Educational Psychology, Ecological Psychology, Industrial and Organizational Psychology, Legal Psychology
PSY152A	APPLICATION OF PSYCHOLOGY TO LIFE	3-1-0-0-11	Nature and Scope of Applied Psychology, Historical Perspective, Areas ofApplied Psychology, Roles and Skills of Applied Psychologists, Ethical Issues, Clinical and Counseling Psychology, Community Psychology and Mental Health, Educational Psychology, Ecological Psychology, Industrial and Organizational Psychology, Legal Psychology
PSY451	PSYCHOLOGY OF ADJUSTMENT	3-1-0--4	The course content, along with lecture wise breakup, is given below. Examinations: Choice of format of the examinations is left to the instructor. Laboratory content: As of now, the time table does not provide an option of introducing the students to laboratory practices. Hence, some demos might be used to enrich the understanding of the course content. **Course Reference**: 1. Wayne Weiten, Dana S Dunn, and Elizabeth Yost Hammer (201 1). Psychology Applied to Modem Life: Adjustment in the 21st Century. Wadsworth publishing (I0 th edition); 2. Robert C. Carson, James Neal Butcher, Susan Mineka (2000). Abnormalpsychology and modem life. Allyn & Bacon (11th edition); 3. W.S. Paine (Ed.) (1984). Job stress and burnout. Sage.
PSY451A	PSYCHOLOGY OF ADJUSTMENT	3-0-0-0-9	The course content, along with lecture wise breakup, is given below. Examinations: Choice of format of the examinations is left to the instructor. Laboratory content: As of now, the time table does not provide an option of introducingthe students to laboratory practices. Hence, some demos might be used to enrich the understanding of the course content. **Course Reference**: 1. Wayne Weiten, Dana S Dunn, and Elizabeth Yost Hammer (2011). Psychology Applied to Modem Life: Adjustment in the 21st Century. Wadsworth publishing (10th edition); 2. Robert C. Carson, James Neal Butcher, Susan Mineka (2000). Abnormal psychology and modem

			life. Allyn & Bacon (11th edition); 3. W.S. Paine (Ed.) (1984). Job stress and burnout. Sage.
PSY454	SOCIAL PSYCHOLOGY	3-1-0--4	Social psychology as a branch of psychology its historical background, Major paradigms of contemporary social psychology, Methods adopted in social psychology, Aggression and violence, Person perception, Social motivation, Attitude and its change, Social facilitation, Social loafing, Social power, Conformity and Compliance, Obedience to authority, Distributive and procedural justice, Group dynamics and intergroup relations, Issues of gender, poverty and marginalization Baron, **Course Reference**: 1. R. A., Branscombe, N. R., & Byrne, D. (2009). Social Psychology (12th ed.). Boston, MA: Pearson/Allyn and Bacon.Gergen, Kenneth J. (1999); 2. An invitation to social construction. Thousand Oaks, CA: Sage.McGarty, C. & Haslam, S. A. (Eds.) (1997); 3. The message of social psychology: Perspectives onmind in society. Oxford, UK and Cambridge, MT: Blackwell.Misra, G. & Dalal, A. K. (Eds.) (2006); 4. New directions in Indian psychology (Vol. 1): SocialPsychology. New Delhi: Sage.Strickland, L. H., Aboud, F. E., & Gergen, K. J. (Eds) (1976); Social psychology in transition. Plenum: New York.
PSY454A	SOCIAL PSYCHOLOGY	3-0-0-0-9	Social psychology as a branch of psychology its historical background, Major paradigms of contemporary social psychology, Methods adopted in social psychology, Aggression and violence, Person perception, Social motivation, Attitude and its change, Socialfacilitation, Social loafing, Social power, Conformity and Compliance, Obedience to authority, Distributive and procedural justice, Group dynamics and intergroup relations, Issues of gender, poverty and marginalization Baron. **Course Reference**: 1. R. A., Branscombe, N. R., & Byrne, D. (2009). Social Psychology (12th ed.). Boston, MA: Pearson/Allyn and Bacon.Gergen, Kenneth J. (1999); 2. An invitation to social construction. Thousand Oaks, CA: Sage.McGarty, C. & Haslam, S. A. (Eds.) (1997); 3. The message of social psychology: Perspectives onmind in society. Oxford, UK and Cambridge, MT: Black well. Misra, G. & Dalal, A. K. (Eds.) (2006); 4. New directions in Indian psychology (Vol. 1): Social Psychology. New Delhi: Sage. Strickland, L. H., Aboud, F. E., & Gergen, K. J. (Eds) (1976); Social psychology in transition. Plenum: New York.
PSY457	INTERPERSONAL DYNAMICS	3-1-0--4	General introduction to the scope of interpersonal dynamics, and themethods used. Major theoretical approaches (Social exchange theory, FIR08, Interpersonal Circumplex). Interpersonal judgment and impression formation (the major models). Interpersonal communication (sending and receiving

			messages, listening skills, communicator style, Transactional Analysis). Interpersonal influence and power. Interpersonal conflict and its management. The social self (self monitoring and self disclosure). Shyness and loneliness as problems in interpersonal relationships. Promoting positive interpersonal dynamics (the role of empathy and emotional intelligence). **Course Reference**: 1. Hinde: Towards Understanding Relationships; 2. Berne: Games People Play. Duck & Gilmour: Personal Relationships.No single textbook is available that covers all the topics included in the course. Therefore, students will be assigned compulsory readings journal articles and book chapters), and will been couraged to read from books that deal with topics relevant to the course.
PSY458	ORGANIZATIONAL AND ADMINISTRATIVE PSYCHOLOGY	3-1-0--4	Organizations and the systems concept, Chronological sequence of development of thought in Organizational Behavior area, A road map for understanding organizatiomil behavior: The elementary aspects of function and structure, their contributions to organizational existence, Organizational models, Attitudes, Job Satisfaction, Motivation and performance, Communication, Conflict and Negotiation, Leadership, Power, Control,Organizational Citizenship, and Antiorganization behaviors, Organizational Change and Organizational Development: Individual and group approaches, Culture and Organizational Behavior, Work Groups, and Significance of individual and group effectiveness through awareness of self and others. This last portion requires experiential learning. **Course Reference**: 1. Katz, D., & Kahn, R.L. (1978). The social psychology of organizations. (2nd ed.). NewYork: John Wiley & Sons; 2. Robbins, S.P. Organizational behavior. New Delhi: Prentice Hall of India Private Limited. (13th edition/ Most Recent Edition/); 3. Sinha, J B P (2008). Culture and organizational behavior. New Delhi: SAGE Publications India Pvt Ltd.
PSY458A	ORGANIZATIONAL AND ADMINISTRATIVE PSYCHOLOGY	3-0-0-0-9	Organizations and the systems concept, Chronological sequence of development of thought in Organizational Behavior area, A road map for understanding organizatiomil behavior: The elementary aspects of function and structure, their contributions to organizational existence, Organizational models, Attitudes, Job Satisfaction, Motivation and performance, Communication, Conflict and Negotiation, Leadership, Power, Control, Organizational Citizenship, and Antiorganization behaviors, Organizational Change and Organizational Development: Individual and group approaches,

			Culture and Organizational Behavior, Work Groups, and Significance of individual and group effectiveness through awareness of self and others. This last portion requires experiential learning. **Course Reference**: 1. Katz, D., & Kahn, R.L. (1978). The social psychology of organizations. (2nd ed.). NewYork: John Wiley & Sons; 2. Robbins, S.P. Organizational behavior. New Delhi: PrenticeHall of India PrivateLimited. (13th edition/ Most Recent Edition/); 3. Sinha, J B P (2008). Culture and organizational behavior. New Delhi: SAGE Publications India Pvt Ltd.
PSY468	SOCIAL COGNITION	3-1-0--4	The major emphasis of the course will be to provide an overview of the individual level social cognitive processes. In addition to this, students will also be exposed toconcepts pertaining to collective and shared sense making and social representations. An analysis based on discursive processes will also be provided in order to understand the cultural underpinning of human social cognition. Overall, the course will foster an understanding of cognitive and social processes of human sense making in the social world. Both, individual levelinformation processing, and collective and symbolic processes of human social life will becovered in the course. Augoustinos, M. and Walker, **Course Reference**: 1. Social Cognition: An Integrated Introduction. London: Sage Publications. 1995; 2. Brewer, M. B. and Hewstone, M (eds.). Social Cognition. Blackwell Publishing: Cornwall, U.K.2004; 3. Fiske, S.T. and Taylor, S.E. Social Cognition. Singapore: McGrawHill. 1991; 4. Kunda, Z. Social Cognition: Making sense of people. MIT Press: Cambridge. 1999; 5. Postmes, T. and Jetten, J (eds.). Individuality and the Group: Advances in Social Identity. SagePublications: London. 2006; 6. In addition to above texts, reading assignments (journal articles and book chapters) will be included from other sources.
PSY468A	SOCIAL COGNITION	3-0-0-0-9	The major emphasis of the course will be to provide an overview of the individual level social cognitive processes. In addition to this, students will also be exposed to concepts pertaining to collective and shared sense making and social representations. An analysis based on discursive processes will also be provided in order to understand the cultural underpinning of human social cognition. Overall, the course will foster an understanding of cognitive and social processes of human sense making in the social world. Both, individual level information processing, and collective and symbolic processes of human social life will be covered in the course. Augoustinos, M. and Walker, **Course Reference**: 1. Social Cognition: An

			Integrated Introduction. London: Sage Publications. 1995; 2. Brewer, M. B. and Hewstone, M (eds.). Social Cognition. Blackwell Publishing: Cornwall, U.K.2004; 3. Fiske, S.T. and Taylor, S.E. Social Cognition. Singapore: McGrawHill. 1991; 4. Kunda, Z. Social Cognition: Making sense of people. MIT Press: Cambridge. !999; 5. Postmes, T. and Jetten, J (eds.). Individuality and the Group: Advances in Social Identity. Sage Publications: London. 2006; 6. In addition to above texts, reading assignments (journal articles and book chapters) will beincluded from other sources.
PSY470A	PSYCHOLOGY OF WELLBEING	3-0-0-0-9	1.Conceptualizing Wellbeing: (a) Nature, definitione and lived experience of wellbeing, (b) Methods in the studey of wellbeing: Quantitative and qualitative approaches; 2. Types of Wellbeing: (a) Objective wellbeing, (b) Psychological wellbeing, (c) Subjective wellbeing and happiness, (d) Quality of Life; 3. Indigenous Approaches to Wellbeing: Experiences and Constructions within the Socio Cultural Contexts; 4. Wellbeing among Specific Groups: Youth, Elderly, Women, Disadvantaged Groups and Disaster Survivors; 5. Indian Psychology of Wellbeing: Perspectives from Samkhya, AdvaitaVedanta and Yoga Systems **Course Reference**: 1. Denzin, N. (1985). Emotions as lived experiences. Symbolic Interaction; 2. Diener, E., & Suh, E.M. (2000); 2. Culture and subjective wellbeing (pp. 185/218). Cambridge, MA: MIT Press; 3. Diener, E., Oishi, S., & Lucas, R. E. (2003). Personality, culture, and subjective wellbeing: Emotional and cognitive evaluations of life. Annual Review of Psychology, 2003, 54, 403,425; 4. Kahneman, D., Diener, E., & Schwarz, N. (Eds.). (1999). Wellbeing: The foundations of hedonic psychology. New York: Russell Sage Foundation; 5. Keyes, Corey L. M. & Haidt, Jonathan (Ed). (2003); 5. Flourishing: Positive psychology and the life well lived. Washington, DC, US: American Psychological Association; 6. Kitayama, S., Markus, H.R. & Kurokawa, M. (2000). Culture, emotion, and wellbeing: Good feelings in Japan and the United States, Cognition and Emotion, 14, 93124; 7. Paranjpe, A.C. (1998). Self and identity in modern psychology and Indian thought. New York: Plenum Press. 11-MAR-2016.
PSY774	QUALITATIVE RESEARCH: THEORY AND PRACTICE	3-0-0-0-4	In the last few years, research in psychology has witnessed a remarkable shiftto a post positivist paradigm. A large number of qualitative methods have emerged in consonance with this shift. For a researcher in psychology. The knowledge of reseach methods and methodological issues is now incomplete without an in depth understanding of the qualitative methods. This course isaimed at providing

			an extensive overview of qualitative research methods, methodological roots, major theoretical principles and issues in qualitative research. Various methods would be discussed along with examples of representations cultural psychology developmental psychology discursive psychology, counseling and psychotherapy.
PSY774A	QUALITATIVE RESEARCH : THEORY AND PRACTICE	3-0-0-0-9	In the last few years, research in psychology has witnessed a remarkable shift to a post positivist paradigm. A large number of qualitative methods have emerged in consonance with this shift. For a researcher in psychology. The knowledge of reseach methods and methodological issues is now incomplete without an in depth understanding of the qualitative methods. This course isaimed at providing an extensive overview of qualitative research methods, methodological roots, major theoretical principles and issues in qualitative research. Various methods would be discussed along with examples of representations cultural psychology developmental psychology discursive psychology, counseling and psychotherapy.
PSY775	FUNDAMENTAL OF NEUROPSYCHOLOGY	3-0-0-0-4	Development and evolution of brain: Brain organization and function; Cerebral asymmetry; Neuropsychology of higher order functions memory language, emotional processes, spatial behaviour; Applied human neuropsychology. **Course Reference**: 1. Barrett, L., Dunbar, R., & Lycett, J. (2002). Human evolutionary psychology, Palgrave Publishers Ltd; 2. Kolb, B. & Whishaw, I.Q. (1990) Fundamentals of human neuropsychology, W.H. Freeman & Company; 3. Mandal, M.K., Bulman Fleming, M.B., & Tiwari, G. (2000); 4. Side Bias: A Neuro psychological Perspective, Kluwer Academic Publishers.
PSY775A	FUNDAMENTAL OF NEUROPSYCHOLOGY	3-0-0-0-9	Development and evolution of brain: Brain organization and function; Cerebral asymmetry; Neuropsychology of higher order functions memory language, emotional processes, spatial behaviour; Applied human neuropsychology. **Course Reference**: 1. Barrett, L., Dunbar, R., & Lycett, J. (2002). Human evolutionary psychology, Palgrave Publishers Ltd; 2. Kolb, B. & Whishaw, I.Q. (1990) Fundamentals of human neuropsychology, W.H. Freeman & Company; 3. Mandal, M.K., Bulman Fleming, M.B., & Tiwari, G. (2000); 4. Side Bias: A Neuropsychological Perspective, Kluwer Academic Publishers.
PSY776	SEMINAR COURSE IN PSYCHOLOGY	----4	Seminar Course in Psychology
PSY776A	SEMINAR COURSE IN PSYCHOLOGY	3-0-0-0-9	Seminar Course in Psychology

PSY780	PSYCHOLOGY OF PERSONALITY	3-0-0--4	Introduction to the field of personality. Trait and situational approaches to personality are covered, along with a critical assessment of the major theories of personality.
PSY783	ADVANCED EXPERIMENTAL SOCIAL PSYCHOLOGY	3-0-0--4	The course includes experimental paradigms in contemporary social psychology covering areas such as attitude and attitude change, group processes, social power, reward allocation, prosocial behavior, social cognition, social influence processes, aggression and violence; and the important theories in social psychology.
PSY784	APPLIED SOCIAL PSYCHOLOGY	3-0-0-0-4	This course will explain how social psycological theories can be applied to reallife. The prime objective is to disseminate findings from behavioural science research which have relevance for problems of society.
PSY786	UNDERSTANDING ORGANIZATIONAL BEHAVIOUR	3-0-0-0-4	A coherent introduction to organizational psychology, historically taking off from industrial psychology and human relations movement. The coursetakes a look at manin organizations in a social environment and concentrates on the theoretically significant empirical research. 21-JUL-2014
PSY786A	UNDERSTANDING ORGANIZATIONAL BEHAVIOUR	3-0-0-0-9	A coherent introduction to organizational psychology, historically taking off from industrial psychology and human relations movement. The course takes a look at manin organizations in a social environment and concentrates on the theoretically significant empirical research.
PSY787	MANAGEMENT OF ORGANIZATIONAL BEHAVIOUR	3-0-0-0-4	The course focuses on a practical training to understand the human behaviour at workin order to predict the effectiveness and wellbeing in various types of organizations, and to enhance the understanding of change processes in these organizations.
PSY787A	MANAGEMENT OF ORGANIZATIONAL BEHAVIOUR	3-0-0-0-9	The course focuses on a practical training to understand the human behaviour at workin order to predict the effectiveness and wellbeing in various types of organizations, and to enhance the understanding of change processes in these organizations.
PSY790	HUMAN COGNITIVE PROCESSES	3-0-0--4	The course deals with scientific study of human mind and explores cognitive processes involved in perception, memory, pattern recognition, psycholinguistics, and bilingualism. Recent research techniques, issues and stands in these areasare critically examined.
PSY790A	HUMAN COGNITIVE PROCESSES	3-0-0-0-9	The course deals with scientific study of human mind and explores cognitive processes involved in perception, memory, pattern recognition, psycholinguistics, and bilingualism. Recent research techniques, issues and stands in these areas are critically examined.

PSY798	ADVANCED COURSE IN SOCIAL COGNITION	3-0-0-0-4	The course aims at providing an understanding of the concepts and issues insocial cognition research. The course contents include historical roots of social congnition; social congnitive principles a cost benefit analysis; representation of social knowledge; social schemas; heuristics and biases; contribution of social representations; rituals and rhetoric; knowledge and social process; social cognition and the study of stereotyping, prejudice and discrimination, social cognition and discourse; social sensibility and neural function.
PSY798A	ADVANCED COURSE IN SOCIAL COGNITION	3-0-0-0-9	The course aims at providing an understanding of the concepts and issues insocial cognition research. The course contents include historical roots of social congnition; social congnitive principles a cost benefit analysis; representation of social knowledge; social schemas; heuristics and biases; contribution of social representations; rituals and rhetoric; knowledge and social process; social cognition and the study of stereotyping, prejudice and discrimination, social cognition and discourse; social sensibility and neural function.
PSY799	PHD THESIS	----	Ph. D. Thesis
SOC171	INTRODUCTORY SOCIOLOGY	3-1-0--4	What is Sociology? Explain how the new science of society came about in the nineteenth century in Western Europe and how it was different from earlier social thought. Discuss the intellectual and social conditions which gave rise to sociology. The Intellectual roots Philosophy of history, political philosophy and the Enlightenment. The socioeconomic roots: The Twin Revolutions, The Industrial Revolution, The French Revolution Theoretical thinking in sociology (A) Classical sociological theorists: Karl Marx Max Weber Emile Durkheim (B) Modern sociological theories: 1. Functionalism and Structural Functionalism Conflict Theory, Symbolic Interactionism Society, Community and Self; 2. lectures Norms, values, roles, custom, status Deviance Theories of subculture; 3. The concept of anomie Sociology of Organizations Different sociological theories of organization Formal and informal organizationsSocial Stratification and Inequality 4.lectures Class Race and Ethnicity Gender Caste Disability Poverty Definition and measurement Extent of poverty Theories of Poverty, Power and Politics. Debating basic concepts in political sociology. Authoritarianism and Democracy. Sociology of Work and Economy Work, nonwork and leisure Taylorsim, Fordism and Post Fordism Sociology of Religion Sociological theories of religion Religious organizations Secularization debates.
SOC171A	INTRODUCTORY SOCIOLOGY	3-1-0-0-11	What is Sociology? Explain how the new science of society came about in the nineteenth century in

			Western Europe and how it was different from earlier social thought. Discuss the intellectual and social conditions which gave rise to sociology. The Intellectual roots Philosophy ofhistory, political philosophy and the Enlightenment. The socioeconomic roots: the Twin Revolutions The Industrial Revolution The French RevolutionTheoretical thinking in sociology (A) Classical sociological theorists: Karl Marx Max Weber Emile Durkheim (B) Modern sociological theories 1. Functionalism and Structural Functionalism Conflict theory Symbolic Interactionism Society, Community and Self, 2. lectures Norms, values, roles, custom, status Deviance Theories of subculture; 3.The concept of anomie Sociology of Organizations Different sociological theories oforganization Formal and informal organizations Social Stratification and Inequality; 4. lectures Class Race and Ethnicity Gender Caste Disability Poverty Definition and measurement Extent of poverty Theories of Poverty, Power and Politics Debating basic concepts in political sociology Authoritarianism and democracy Sociology of Work and Economy Work, nonwork and leisure Taylorsim, Fordism and Post Fordism Sociology of Religion Sociological theories of religion Religious organizations Secularization debates
SOC171B	INTRODUCTORY SOCIOLOGY	3-1-0-0-11	What is Sociology? Explain how the new science of society came about in the nineteenth century in Western Europe and how it was different from earlier social thought. Discuss the intellectual and social conditions which gave rise to sociology. The Intellectual roots Philosophy ofhistory, political philosophy and the Enlightenment. The socioeconomic roots: the Twin Revolutions The Industrial Revolution The French Revolution Theoretical thinking in sociology(A) Classical sociological theorists: Karl Marx Max Weber Emile Durkheim(B) Modern sociological theories. 1. Functionalism and Structural Functionalism Conflict theory Symbolic Interactionism Society, Community and Self; 2. lectures Norms, values, roles, custom, status Deviance Theories of subculture; 3.The concept of anomie Sociology of Organizations Different sociological theories of organization Formal and informal organizations Social Stratification and Inequality; 4. lectures Class Race and Ethnicity Gender Caste Disability Poverty Definition and measurement Extent of poverty Theories of Poverty, Power and Politics Debating basic concepts in political sociology Authoritarianism and democracy Sociology of Work and Economy Work, nonwork and leisure Taylorsim, Fordism and Post Fordism Sociology of Religion Sociological theories of religion Religious organizations Secularization debates

SOC171C	INTRODUCTORY SOCIOLOGY		What is Sociology? Explain how the new science of society came about in the nineteenth century in Western Europe and how it was different from earlier social thought. Discuss the intellectual and social conditions which gave rise tosociology. The Intellectual roots Philosophy of history, political philosophy and the Enlightenment. The socioeconomic roots: The Twin Revolutions.The Industrial Revolution, The French RevolutionTheoretical thinking in sociology (A) Classical sociological theorists: Karl Marx Max Weber Emile Durkheim (B) Modern sociological theories 1. Functionalism and Structural Functionalism Conflict Theory Symbolic Interactionism Society, Community and Self; 2. lectures Norms, values, roles, custom, status Deviance Theories of subculture; 3. The concept of anomie Sociology of Organizations Different sociological theories of organization Formal and informal organizations Social Stratification and Inequality; 4. lectures Class Race and Ethnicity Gender Caste Disability Poverty Definition and measurement Extent of poverty Theories of Poverty, Power and Politics Debating basic concepts in political sociology Authoritarianism and democracy Sociology of Work and Economy Work, nonwork and leisure Taylorsim, Fordism and Post Fordism Sociology of Religion Sociological theories of religion Religious organizations Secularization debates.
SOC173	INTRODUCTION TO INDIAN SOCIETY	3-1-0--11	Indian Sociology: An Introduction, Social Roots of Indian Society: Vedic heritage, Brahminic, Islamic, British, Indian Social Structure: Rural Context, Urban Context, Indian Social Institutions and Organisations Family, Marriage, Jajmani Relation, Caste and Tribe, Religion and education, Social Movements in India: Reformist, Nationalist, Agrarian, Backward Caste, Processes of Social Change in India, Westernization, Sanskritisation, Contemporary Social Problems. Secularism, Common civil code, Reservation policy, Demographic transition, etc.
SOC173A	INTRODUCTION TO INDIAN SOCIETY	3-1-0-0-11	The question of identification Postive Discrimination: Features, Legal provisions Family and Kinship:Family as a functional unit; Types of family; Kinship usage Hindu marriage:Aims, Age, Preference and restrictions; Polyandry; Polygyny; Sati; Widow remarriage, Dowry Marriage among Muslims: Historical background; Types of marriage; Mahr; Divorce; Recent changes Marriage among Christians: Historical background and changes Religious Traditions: Hinduism, Buddhism, Jainism, Sikhism, Islam Secularism; Reliqious violence Social Movements: Revivalist, Reformist, Peasant, Trade Union movements
SOC470	SOCIOLOGY OF DEVELOPMENT	3-1-0--4	Objectives of the course is to portray the process of development and underdevelopment from

			asociological perspective. Being essentially a theory based course, it would analyse the process of development from various theoretical perspectives that have been dominant at different periods oftime in intellectual traditions of sociology; 1. Defining the concept of Development: Sociocultural factors; 2. The modernization perspective of development (the Structural Functional view): Its intellectual heritage classical modernization studies (Sociological aspects, political aspects, economic aspects, Psychological aspects), its assumptions, its methodology and itslimitations; 3. The Modernisation perspective: New modernization studies; 4. The Dependence perspective of development (the NeeMarxist view): Its intellectual heritage, the classical dependence studies (theories of underdevelopment), Dependence perspective: Its assumptions, its methodology and its limitations; 5. The Dependence Perspective of development: New dependence studies; 6. The World System Perspective: Its intellectual heritage, Contributions of Immanuel Wallerstein, the theory of world capitalist system, its assumptions, its methodology and its limitations. 7. World system studies at Global level, Powers of world system perspective; 8. Global System Interdependence, New Structural analysis, agent centered analyses, a new substantive focus Dynamics of complexchange; 9. Globalization (neo Liberalism), Development reconsidered voices of Dissent and alternatives. **Course Reference**: 1. Alvin Y So, 2005, Social Change and Development, Sage publications, Thousand Oaks; 2. P W Preston, 2001, Development Theory and Introduction, Blackwell Publishers. David Lehmann, 1989, Development Theory, Frank Cass; 3. Eisenstadt 5 N, 1979, Modernization Protest and Change, Prentice Hall, EEE.
SOC470A	SOCIOLOGY OF DEVELOPMENT	3-0-0-0-9	Objectives of the course is to portray the process of development and underdevelopment from a sociological perspective. Being essentially a theory based course, it would analyse the process of development from various theoretical perspectives that have been dominant at different periods of time in intellectual traditions of sociology.1 Defining the concept of Development: Sociocultural factors, 2 The modernization perspective of development (the Structural Functional view): Its intellectual heritage classical modernization studies (Sociological aspects, political aspects, economic aspects, Psychological aspects), its assumptions, its methodology and its limitations, 3 The Modernisation perspective: New modernization studies. 4 The Dependence perspective of development (the Nee Marxist view): Its intellectual heritage, the classical dependence studies (theories of underdevelopment), Dependence

			perspective: Its assumptions, its methodology and its limitations.5 The Dependence Perspective of development: New dependence studies.6 The World System Perspective: Its intellectual heritage, Contributions of Immanuel Wallerstein, the theory of world capitalist system, its assumptions, its methodology and its limitations.7 World system studies at Global level, Powers of world system perspective. 8 Global System Interdependence, New Structural analysis, agent centered analyses, a new substantive focus Dynamics of complex change. 9 Globalization (neo Liberalism), Development reconsidered voices of Dissent and alternatives. **Course Reference**: 1. Alvin Y So, 2005, Social Change and Development, Sage publications, Thousand Oaks; 2. P W Preston, 2001, Development Theory and Introduction, Blackwell Publishers; 3. David Lehmann, 1989, Development Theory, Frank Cass; 4. Eisenstadt 5 N, 1979, Modernization Protest and Change, Prentice Hall, EEE.
SOC473	INDIAN SOCIETY AND CULTURE	3-1-0--4	Approaches to study Indian Society. Social stratification: caste, jati and varna among Hindus, nonHindus. Marriage and Family among Hindus, Muslims and Christians; polyandry and polygyny; regulations of marriage, separation and divorce. Kinship organization in India. Concepts and approaches to social change in India: Sanskritization and Westernization; parochialization and universalization; structural, dialectical, cognitive historical, and indological approaches. Ortilogenelic processes of cultural change in culture traditions and modernization. Heterogenetic processes of cultural change in culture traditions and modernization. Recent processes of change: peasant religious and sectarian movements; dalit and backward caste movements; tribal, labour movements. New Social Movement: Ecological Movement Dumont, Louis. Homo Hierarchius: **Course Reference**: 1. The Caste System and its Implications London: Weidenfeld and Nicholson, 1970; 2. Ghurye, G. S. Caste and Race in India. Mumbai: Popular Prakashan, 1969, 5th edition. Gupta, Dipankar, editor. Social Stratification. New Delhi: Oxford University Press,1991; 3. Kapadia, K. M. Marriage and Family in India. Calcutta: Oxford University Press,1966; 4. Rao, M. S. A. Social Movements and Social Transformation: A Study of Two Backward Classes Movements in India. New Delhi: Macmillan, 1979; 5. Shah, Ghanshyam. Social Movements in India: A Review of the Literature. NewDelhi: Sage, 1990. Singh, Yogendra. Modernization of Indian Tradition. Jaipur: Rawat Publications, 1986 (reprint); 6. Srinivas, M. N. Social Change in Modern India. New Delhi: Orient

			Longman,1995 (reprint 2002).
SOC473A	INDIAN SOCIETY AND CULTURE	3-0-0-0-9	Approaches to study Indian Society. Social stratification: caste, jati and varna among Hindus, nonHindus. Marriage and Family among Hindus, Muslims and Christians; polyandry and polygyny; regulations of marriage, separation and divorce. Kinship organization in India. Concepts and approaches to social change in India: Sanskritization and Westernization; parochialization and universalization; structural, dialectical, cognitive historical, and indological approaches. Ortilogenelic processes of cultural change in culture traditions and modernization. Heterogenetic processes of cultural change in culture traditions and modernization. Recent processes of change: peasant religious and sectarian movements; dalit and backward caste movements; tribal, labour movements. New Social Movement: Ecological Movement Dumont, Louis. Homo Hierarchius: **Course Reference**: 1. The Caste System and its Weidenfeld and Nicholson, 1970. Ghurye, G. S. Caste and Race in India. Mumbai: Popular Prakashan, 1969, 5thedition.Gupta, Dipankar, editor. Social Stratification. New Delhi: Oxford University Press,1991; 2. Kapadia, K. M. Marriage and Family in India. Calcutta: Oxford University Press,1966; 3. Rao, M. S. A. Social Movements and Social Transformation: A Study of Two Backward Classes Movements in India. New Delhi: Macmillan, 1979; 4. Shah, Ghanshyam. Social Movements in India: A Review of the Literature. NewDelhi: Sage, 1990; 5. Singh, Yogendra. Modernization of Indian Tradition. Jaipur: Rawat Publications,1986 (reprint). Srinivas M. N. Social Change in Modern India. New Delhi: Orient Longman,1995 (reprint 2002).
SOC474	INDUSTRIAL SOCIOLOGY	3-1-0--4	1.Industrial Sociology nature and scope, Evolution of Industry as a productive system, 2. Formal organization: Bureaucracy and its functions, 3. Roles of Executives in bureaucratic organizations, Functions of Executives, 4. Informal Organizations: importance of human relations at work, Patterns of communications in Informal organizations, Importanceof informal organizations, Group dynamics, OS Industrial Relations: Trifold role: management (Employers Associations/ Federations), labour (national/ International organizations) and government (Labour legislations/ labour courtsand adjudications) global experiences; 6. Role of labour and work in industry, Labour problems, Social structure of Trade unions, Trade Unionism (in India) and labour policies in India (through five year plans), 7. Industrial conflicts, and conflict resolution mechanisms: Collective bargaining and Grievance procedures, and Changing nature of occupations,

			Embourgeoisement, unionism vrs. Professionalism; 8. Participatory Management Issues (Indian as well as Global experiences), **Course Reference**: 1. Monappa Arun,2006, Industrial Relations, Tata McGrawhill publishing Co.(Reprint); 2. Stephen Edgell, 2006, The Sociology of work, Sage publications; 3. Schnieder E V, 1972, Industrial Sociology, The social relations of Industry and the community,Tata McGrawhill Publishing co; 4. Shils Edward, 1963, Automation and Industrial relations, Holt Rinehart and Winston; 5. Ivar E Berg, 1981, Sociological Perspectives on La pour markets, Academic Press; 6. Forsyth, D.R. 2010. Group Dynamics, 5th Edition. Belmont, CA: Thomson Wadsworth; 7. Watson Tony J, 2004, Sociology, Work and Industry, New York: Routledge reprint.; 8. Miller DC and W H Form,1968, Industrial Sociology, London: Harper & Row; 9. Parker Stanley Robert, 1981. The Sociology of Industry, Allen and Unwin.
SOC477	URBAN HABITAT AND SOCIAL INTERACTION	3-1-0--4	From rural to urban: debates around the concepts of gemeinschaft and gesellschaft; Origin of city in history; Theories of urban sociology (Classical and Contemporary); Technology and urban life; Poetics and politics of urban spaces; Urban planning and design; Rural, urban, rururban; and suburban: the future of urban sociology. **Course Reference**: 1. Rao, M. S. A., ed. (1974) Urban Sociology in India: Reader and Source Book. New Delhi: Orient Longman.Gottdiener, Mark and Ray Hutchison (2006); 2. The New Urban Sociology. Boulder: West View Press. Gottdiener, Mark and Leslie Budd (2005); 3. Key Concepts in Urban Studies. London: Sage Publications.Karp David eta! (1977); 4. Being Urban: A Sociology of City Life. Lexington, Mass: D. C. Heatb and Company.Lin Jan and Mele Christopher, ed. (2005); 5. The Urban Sociology Reader. London: Routledge. Palen, J. John. (2008); 6. The Urban World. Boulder: Paradigm Publishers. David Pinder. (2005); 7. Visions of the City; Utopianism, Power and Politics in Twentieth CenturyUrbanism. New York: Routledge.
SOC477A	URBAN HABITAT AND SOCIAL INTERACTION	3-0-0-0-9	From rural to urban: debates around the concepts of gemeinschaft and gesellschaft; Origin of city in history; Theories of urban sociology (Classical and Contemporary); Technology and urban life; Poetics and politics of urban spaces; Urban planning and design; Rural, urban, rururban and suburban: the future of urban sociology. **Course Reference**: 1. Rao, M. S. A., ed. (1974) Urban Sociology in India: Reader and Source Book. NewDelhi: Orient Longman.Gottdiener, Mark and Ray Hutchison (2006); 2. The New Urban Sociology. Boulder: WestView Press.Gottdiener, Mark and Leslie Budd (2005); 3. Key Concepts in Urban

			Studies. London: SagePublications.Karp David eta! (1977); 4. Being Urban: A Sociology of City Life. Lexington, Mass: D. C. Heatb and Company.Lin Jan and Mele Christopher, ed. (2005); 5. The Urban Sociology Reader. London: Routledge. Palen, J. John. (2008); 6. The Urban World. Boulder: Paradigm Publishers. David Pinder. (2005); 7. Visions of the City; Utopianism, Power and Politics in Twentieth Century Urbanism. New York: Routledge.
SOC479	POPULATION, ECONOMY AND SOCIETY	3-0-0--4	Relationship between demographic trends and the socioeconomic context; Demography and population studies; World population growth; Population of India; Population theories; Data and methods in population studies; Population policies; Population policy in India; **Course Reference**: 1.HIV I AIDS and reproductive health. Davis, Kingsley (1968); 2. The Population of India and Pakistan. New York: Russell and Russell.Sharma, A. K. (2011) Population and Society. New Delhi: Concept Publishing Company Pvt.Ltd. Shryock, Hemy S., Siegel, Jacobs, and associates (1971); 3. The Methods and Materials of Demography. New York: U.S. Bureau of Census.Smith David, and Keyfitz, Nathan (1977); 4. Mathematical Demography. Berlin: SpringerVerlag.Smith, David P. (1992); 5. Formal Demography. New York: Plenum Press.Sorokin, Pitirim (1978) Contemporary Sociological Theories. Ludhiana: Kalyani Publishers.United Nations (1973) The Determinants and Consequences of Population Trends. Vol. 1 NewYork: United Nations.United Nations (1974) Methods of Projections of Urban and Rural Population; 6. New York: United Nations.United Nations (1983) Indirect Techniques for Demographic Estimation. New York: United Nations.
SOC479A	POPULATION, ECONOMY AND SOCIETY	3-0-0-0-9	Relationship between demographic trends and the socioeconomic context; Demography and population studies; World population growth; Population of India; Population theories; Data and methods in population studies; Population policies; Population policy in India; HIV I AIDS and reproductive health. **Course Reference**: 1. Davis, Kingsley (1968) The Population of India and Pakistan. New York: Russell and Russell.Sharma; 2. A. K. (2011) Population and Society. New Delhi: Concept Publishing Company Pvt.Ltd. Shryock, Hemy S., Siegel, JacobS., and associates (1971); 3. The Methods and Materials of Demography. New York: U.S. Bureau of Census.Smith David, and Keyfitz, Nathan (1977); 4. Mathematical Demography. Berlin: SpringerVerlag.Smith, David P. (1992) Formal Demography. New York: Plenum Press.Sorokin, Pitirim (1978) Contemporary Sociological Theories. Ludhiana: Kalyani Publishers.United Nations (1973);

			5. The Determinants and Consequences of Population Trends. Vol. 1 NewYork: United Nations.United Nations (1974); 6. Methods of Projections of Urban and Rural Population. New York: United Nations.United Nations (1983) Indirect Techniques for Demographic Estimation. New York: United Nations.
SOC481	SOCIETY AND SOCIAL PROBLEMS OF INDIA	3-0-0-0-4	Sociological perspectives on social problems; Social change; Interaction between structural and cultural components in the process of social change; Major social problems of India such as social and economic inequality, unemployment, illiteracy, high dropout rate in schools, gender gap, population problem, bad governance, communalism and terrorism; The concept of inclusive growth. **Course Reference**: 1. Beteille, Andre (2000) Antinomies of Society: Essays on Ideologies & Institutions; 2. New Delhi: Oxford University Press.Dumont, Louis (1970) Homo Hierachicus; 3. London: Paladin, Granada Publishing Ltd.English, Richard (2009); 4. Terrorism: How to Respond Oxford: Oxford University Press.Planning Commssion (2008). Eleventh FiveYear Plan, 200712. New Delhi: Oxford University Press; 5. Srinivas, M.N. (1966) Social Change in Modern India. Berkeley: California University Press.
SOC481A	SOCIETY AND SOCIAL PROBLEMS OF INDIA	3-0-0-0-9	Sociological perspectives on social problems; Social change; Interaction between structural and cultural components in the process of social change; Major social problems of India such as social and economic inequality, unemployment, illiteracy, high dropoutrate in schools, gender gap, population problem, bad governance, communalism and terrorism; The concept of inclusive growth. **Course Reference**: 1. Beteille, Andre (2000) Antinomies of Society: Essays on Ideologies & Institutions; 2. New Delhi: Oxford University Press.Dumont, Louis (1970) Homo Hierachicus; 3. London: Paladin, Granada Publishing Ltd.English, Richard (2009); 4. Terrorism: How to Respond Oxford: Oxford University Press.Planning Commssion (2008) Eleventh Five Year Plan, 200712. New Delhi: Oxford University Press; 5. Srinivas, M.N. (1966) Social Change in Modern India. Berkeley: California University Press.
SOC482A	SOCIOLOGY OF GLOBALIZATION	3-0-0-0-9	Defining Globalization: a. Flows and Structures, b. Key Debates, c. Related Processes. Socio Economic Aspects of Globalization: a. Neoliberalism, b. Global Economic Structuresc. c. Global Economic Flows. Globalization and political structures and processes: Culture and Globalization. Hightech flows and structures. Flows of people. Environmental Flows. Globalization and Social Stratification: a. Urban Rural, b. Gender and Sexuality, c. Class, d. Race,

			Ethnicity and Caste. Ritzer, George. 2010. Globalization: A Basic Text. Chichester: Wiley Blackwell.Ritzer, George and Zeynep Atalay, eds. 2010. Readings in Globalization: Key Concepts and Major Debates. Chichester: Wiley Blackwell. Additional Readings: Journal articles and book excerpts may be assigned periodically to the students. These, readings will be assigned to students well in advance. 11-MAR-2016
SOC486	HUMAN RIGHTS THEORY AND PRACTICE	3-1-0--4	1. Introduction: Magna Carta, English Bill of Rights, American/French Declaration, Universal Declaration of Human Rights: Background, Content and Relevance; 2. Theories/Justification/ Perspectives on Human Rights: Natural, Moral and Legal; Natural rights, Positivist, Liberal, Marxist, Feminist, Asian perspectives; 3. Debates: Universality of Rights; Rights Vs Duties; Individual Vs Group Rights; Civil and Political Rights Vssocial, Economic and cultural rights; 4. The notion of rights in various religious traditions (Hindu, Muslim, Buddhist traditions); 5. Western Influence (especially the impact of the British rule); National Freedom Movement, and the roles of Gandhi, Ambedkar and Nehru); 6. Inter governmental Organization: The United Nations (study of specific UN agencies related to human rights);Regional Instruments; 7. International NGO Amnesty International its working and impact on India; 8. Constitutional Developments in India: Constitutional Provisions (especially Fundamental Rights Vs DirectivePrinciples of State_Policy) and Emergency; 9. Case Studies of Selected National NGOs;10. Case Studies of Selected Regional NGOs; 11. National Human Rights Commission of India:Background, Structure and Functioning;12. The Judiciary, including Public Interest Litigation;13. International Humanitarian Law; International Refugee Law;14. Some Issues in Human Rights: Violence and Terrorism; Women’s Rights, Child Rights, Dalit Rights,Minority Rights, Tribal Rights, Capital Punishment, Euthanasia, Rights of the Elderl) **Course Reference**: 1. Gay Rights Basu, D. D. Introduction to the Constitution of India. New Delhi: Prentice Hall,2008, 18th edition; 2. Desai, A. R., editor. Violation of Democratic Rights in India, 3 volumes, Mumbai: Popular Prakashan, 19861991; 3. Donnelly Jack. Universal Human Rights in Theory and Practice. Ithaca: Cornell University Press, 2003; 4. Fakuda Parr, Sakiko and A. K. Shiva Kumar, editors. Readings in Human Development: Concepts, Measures and Policies for a Development Paradigm. New Delhi: Oxford University Press, 2003; 5. Mohanty, Manoranjan, Partha Nath Mukherji, with Olle Tornquist, editors. People’s Rights: Social Movements and the State in the Third World.New

			Delhi: Sage Publications, 1998; 6. Nanda, Ved P., James R. Scarritt and George W Shepherd, Jr., editors. Global Human Rights: Public Policies, Comparative Measures and NGO Strategies. Boulder: Westview Press Inc., 1981.
SOC486A	HUMAN RIGHTS THEORY AND PRACTICE	3-0-0-0-9	1. Introduction: Magna Carta, English Bill of Rights, American/French Declaration, Universal Declaration of Human Rights: Background, Content and Relevance; 2. Theories/Justification/ Perspectives on Human Rights: Natural, Moral and Legal; Natural rights, Positivist, Liberal, Marxist, Feminist, Asian perspectives; 3. Debates: Universality of Rights; Rights Vs Duties; Individual Vs Group Rights; Civil and Political Rights Vssocial, Economic and cultural rights; 4. The notion of rights in various religious traditions (Hindu, Muslim, Buddhist traditions); 5. Western Influence (especially the impact of the British rule); National Freedom Movement, and the roles ofGandhi, Ambedkar and Nehru); 6. Inter governmental Organization: The United Nations (study of specific UN agencies related to human rights);Regional Instruments; 7. International NGO Amnesty International its working and impact on India; 8. Constitutional Developments in India: Constitutional Provisions (especially Fundamental Rights Vs DirectivePrinciples of State_Policy) and Emergency; 9. Case Studies of Selected National NGOs;10. Case Studies of Selected Regional NGOs; 11. National Human Rights Commission of India:Background, Structure and Functioning;12. The Judiciary, including Public Interest Litigation;13. International Humanitarian Law; International Refugee Law;14. Some Issues in Human Rights: Violence and Terrorism; Women's Rights, Child Rights, Dalit Rights,Minority Rights, Tribal Rights, Capital Punishment,Euthanasia, Rights of the Elderl) **Course Reference**: 1. Gay Rights Basu, D. D. Introduction to the Constitution of India. New Delhi: Prentice Hall,2008, 18th edition; 2. Desai, A. R., editor. Violation of Democratic Rights in India, 3 volumes, Mumbai: Popular Prakashan, 19861991.Donnelly Jack. Universal Human Rights in Theory and Practice; 3. Ithaca: Cornell University Press, 2003.FakudaParr, Sakiko and A. K. Shiva Kumar, editors. Readings in Human Development: Concepts, Measures and Policies for a Development Paradigm. New Delhi: Oxford University Press, 2003; 4. Mohanty, Manoranjan, Partha Nath Mukherji, with Olle Tornquist, editors. People's Rights: Social Movements and the State in the Third World. New Delhi: Sage Publications, 1998; 5. Nanda, Ved P., James R. Scarritt and George W Shepherd, Jr., editors. Global Human Rights: Public Policies, Comparative Measures and NGO Strategies.

			Boulder: Westview Press Inc., 1981.
SOC489	EXPLORING HUMAN VALUES: VISIONS OF HAPPINESS AND PERFECT SOCIETY	3-1-0-0-4	1. The problem Twin goals: happiness and just order; role of value education; 2. Paradoxes of happiness Concepts of good life quality of life and subjective well being; happiness, life satisfaction, and positive affect; studying quality of life through surveys; and findings of quality of life surveys; 3. The problem of social Moral and institutional approaches; and the inherent conflict transformation between the two; 4. Conceptualizing the Man and society; theories of man and society such as relationship between methodological individualism, structuralism, Gidden's theory man and society of structuration, and structural symbolic interactionism; 5. Religious and spiritual Vedic, Jain and Buddhist philosophies; Christianity; Islam; approaches to human and Sikhism happiness; 6. Economic and utilitarian Utilitarianism; utility and economic theory; capitalism: claims theories of capitalism; internal contradictions; socialism andcommunism; disorganized capitalism; risk; 7. Political approaches Marxist and neoMarxist thoughts; critical theory; democracy in public and private spheres; manifestos of leading politicaloarties; 8. An argument for Nehruvian model of industrial socialism; inclusive growth modernization and development; 9. Post modernization and Modernization and postmodernization; emancipation; emancipation emancipatory practices; dilemmas and paradoxes; 10. Possibilities of Hope and hopelessness; transforming society; professional transformation ethics; 11. Indian social thoughts Attempts to combine spiritual, economic and political theories of values: Rammohan Roy, Aurobindo, Tagore, Gandhi, Ambedkar, kumarswamy; 12. Human values and Jeevan Vidya; human values and need for humanism: dilemmas harmony in the self; harmony with the body; harmony inand directions family, society, nature and existence; evaluation of Jeevan Vidya; 13. **Course Reference**: 1. Conclusion Summary and conclusion of the course Agrawal, S.P., and J.C. Aggarwal, Educational and Social Uplift of Backward Classes: At What Cost and How? Manda! Commission and After, New Delhi: Concept Publishing Company,1991; 2. Ahmed, Hila! Debating Muslim Political Representation. http://www.indiaseminar.com/2008/586/586aluned.htm [accessed on 5 October 2009]. Ambedkar, B. R., Buddha and his Dhamma, http://www.scribd.com/doc/16634512/Buddhaand His Dhanuna by B R Ambedkar Full [accessed on 21 October, 2010]; 3. Beck, Ulrich, Risk Society: Towards a New Modernity, tr. by Ritter, Mark, London: Sage Publications, 1992; 4. Beteille, Andre;

			Beyond Minority Reports, The Times of India, 12 October, 2009, p. 10.Beteille, Andre, Antinomies of Society: Essays on Ideologies & Institutions. New Delhi: Oxford University Press, 2000.
SOC720	RESEARCH METHODS	3-0-0--4	Nature and types of scientific explanation, Values and objectivity in social scienceresearch, Various research designs: (i) Descriptive, (ii) Exploratory, (ii) Experimental (two and multigroup designs). Tools and techniques of data collection, both direct and indirect methods of data collection (projective techniques), Various scaling techniques (Differential scales, Summated scalesand Cumulative scales, etc), problems of measurement, Various types of reliability and validity of measures, Qualitative research.
SOC720A	RESEARCH METHODS	3-0-0-0-9	Nature and types of scientific explanation, Values and objectivity in social science research, Various research designs: (i) Descriptive, (ii) Exploratory, (ii) Experimental (two and multigroup designs). Tools and techniques of data collection, both direct and indirect methods of data collection (projective techniques), Various scaling techniques (Differential scales, Summated scales and Cumulative scales, etc), problems of measurement, Various types of reliability and validity of measures, Qualitative research.
SOC721	SOCIOLOGICAL THEORY	3-0-0--4	Relation between theory and research. The nature and use of theory, basic concepts, fundamental perspectives of society, conceptualization of social system social structure and culture, Various perspectives; Structural Functional, conflict Theory Frankfurt school critical theory, Exchange theory, Symbolic Interactionism, Phenomenology, Ethno methodology and Structuration theory.
SOC721A	SOCIOLOGICAL THEORY	3-0-0-0-9	Relation between theory and research. The nature and use of theory, basic concepts, fundamental perspective of society, conceptualization of social system, social structure and culture, Various perspectives; Structural Functional, conflict Theory Frankfurt school critical theory, Exchange theory, Symbolic Interactionism, Phenomenology, Ethnomethodology and Structuration theory.
SOC723	INTRODUCTION TO STATISTICAL INFERENCE	3-0-0--4	Basic statistics; correlation and regression analysis; probability and probability distributions; sampling designs; tests of significance; analysis of variance; nonparametric methods; recent developments in applied statistics in social sciences.
SOC732	SOCIOLOGY OF DEVELOPMENT	3-0-0--4	Sociological perspective on development problems with special reference to India, theories/models of development, Modernization Theory (New modernization studies) Dependence Theory (New dependence studies), World System Theory, Global system Interdependence, Globalization, UNDP

			definition of Development indicators. The sustainable nature of Development, Development reconsidered voices of Dissent.
SOC734	SOCIAL INEQUALITY AND STRATIFICATION	3-0-0--4	Critical evaluation of concepts and theories of social inequality and stratification; aspects of inequality in contemporary societies; methodology of stratification; stratification in India.
SOC742A	SOCIOLOGY OF ENVIRONMENT	3-0-0-0-9	The new environmental paradigm in sociology. The relationship between environment and social complex; Environmentalism and Development (issue of socioeconomic equities). The concept of sustainable development in environmental studies. Social response to environmental imperatives (Role of value structure, normative and attitudinal patterns in communities). Social Institutions in the context of environmentalis, e.g. Roligion, caste, tribe, local communities and voluntary associations. Environmental movements and their impacts.
SOC745	SOCIAL THEORY IN LATE TWENTIETH CENTURY	3-0-0-0-4	Canons in sociological theory, breaking with modernity, post positivist and post structural social thought, post modernism in social theory: present images andfuture possibilities, Writings of J Baudrillard, Michel Foucault, J F Lyotard, JDerrida, and F Jameson.
SOC745A	SOCIAL THEORY IN LATE TWENTIETH CENTURY	3-0-0-0-9	Canons in sociological theory, breaking with modernity, post positivist and poststructural social thought, post modernism in social theory: present images and future possibilities, Writings of J Baudrillard, Michel Foucault, J F Lyotard, JDerrida, and F Jameson.
SOC746	SOCIAL MOVEMENTS: OLD AND NEW	3-0-0--4	The aim of the course is to define the various types of social movements, and understand their role in striving for social change or transformation. It will examine theories of social movements in the context of recent debates surrounding issues of nationalism, ethnicity, and identity. Specific movements, including the role of various actors, will be studied with special reference toIndia.
SOC746A	SOCIAL MOVEMENTS: OLD AND NEW	3-0-0-0-9	The aim of the course is to define the various types of social movements, and understand their role in striving for social change or transformation. It will examine theories of social movements in the context of recent debates surrounding issues of nationalism, ethnicity, and identity. Specific movements, including the role of various actors, will be studied with special reference to India.
SOC748	EDUCATION AND SOCIAL CHANGE	----4	General introduction to the place of learning in society. Learning, education and training. Changing meanings of education across time and society. A brief historical perspective on education in India. Social political arithmetic as aspurious way of understanding education and social change.

			Structural functionalist perspectives and structural conflict perspectives on education. Class, conflict, legitimation processes, reproduction of society. Anarchist perspectives. New Sociology of Education. Symbolic interactionist perspectives on education. Resistances to schooling. Critical theory and education. NeoWeberian perspectiveson education. Status politics and education. Caste, class, gender andeducation in India. Indian thinkers on education. Current debates on the placeof education in India.
SOC749	CONTEMPORARY SOCIAL THEORY	3-0-0-0-4	Theories of risk society, structuration, disorganized capitalism, social and cultural capital, standpoint theory, postmodernism, and complexity theory. Major contributions of Ulrich Beck, Anthony Giddens, Scott Lash, John Urry, Dorothy Smith, Pierre Bourdieu, Zygmunt Bauman, Michel Foucault and Jean Baudrillard. 18-SEP-14
SOC750	SOCIOLOGY OF RELIGION	3-0-0-0-4	Committed to the binary opposition between Reason and religion the evolutionary theorists believed that religion signified the childhood of human race. The Enlightenment theories had professed the decline and subsequent disappearance of religion. But the events since the second half of the twentieth century have provedthis prediction to be wrong. The resurgence of the religious in contemporary times calls for a fresh appraisal of the theories of sociology of religion. The coursewill introduce the seminal theories in sociology of religion. It will explore therelation between religion and other areas of social life such as economy and polity. The diachronic processes within religion, i.e., movements, sect formation, institutional forms as well as organizational dynamics will be addressed in this course. Finally, the course will also explore the issues of secularization and civil religion.
SOC751	METHODS OF SOCIOLOGICAL RESEARCH	3-0-0-0-4	Relation between theory and method and the concept of paradigm Quantitative Research Methods: Experimental design and surveys; different types of experimental designs; longitudinal studies; sampling techniques. Qualitative Research Methods: Ethnography, casestudies, historical and documentary research. Major data sources and their use in the historical and documentary study of Indian society and culture: Census, Archival material, National Sample Survey, Gazetteers and District Handbooks and other large data sets Brewer, Jonhn and Albert Hunter. **Course Reference**: 1. Multimethod Research, Sage, 1989.Clifford, James and G. Marcus, Writing Cultures: Poetics and Politics of Ethnography, University of California Press, 1986. Cochran, William. G. Sampling Techniques, Wiley, 1999; 2. Durkheim, Emile. Suicide: Study in Sociology. Free Press, 1968; 3. (Book Two. pp. 145294) Epstein, A.

			L. (ed) The Craft of Social Anthropology, Tavistock, 1967; 4. Flick, Uwe. An Introduction to Qualitative Research, Sage, 2002.Geertz, C. The Interpretation of Cultures. Basic Books, 1963. (Chapter 15). Hammersley, Martyn. The Dilemma of Qualitative Method, Routledge, 1989; 5. Kanji, Gopal K. Statistical Tests, Sage,1993. LeviStrauss, C. Structural Anthropology; 6. Basic Books 1963. (Part 1 pp. 3791) Luckacs, George. History and Class Consciousness. Merlin Press, 1971. (Chapter 1) Margolis, Eric (ed), The Sage Handbook of Visual Research, Sage, 2011. 17-SEP-14
SOC751A	METHODS OF SOCIOLOGICAL RESEARCH	3-0-0-0-9	Relation between theory and method and the concept of paradigm Quantitative Research Methods: Experimental design and surveys; different types of experimental designs; longitudinal studies; sampling techniques. Qualitative Research Methods: Ethnography, casestudies, historical and documentary research. Major data sources and their use in the historical and documentary study of Indian society and culture: Census, Archival material, National Sample Survey, Gazetteers and District Handbooks and other large data sets. Brewer, Jonhn and Albert Hunter. **Course Reference**: 1. Multimethod Research, Sage, 1989. Clifford, James and G. Marcus, Writing Cultures: Poetics and Politics of Ethnography, University of California Press, 1986. Cochran, William. G. Sampling Techniques, Wiley, 1999; 2. Durkheim, Emile. Suicide: Study in Sociology. Free Press, 1968; 3. (Book Two. pp. 145294) Epstein, A. L. (ed) The Craft of Social Anthropology, Tavistock, 1967; 4. Flick, Uwe. An Introduction to Qualitative Research, Sage, 2002.Geertz, C. The Interpretation of Cultures. Basic Books, 1963. (Chapter 15). Hammersley Martyn. The Dilemma of Qualitative Method, Routledge, 1989; 5. Kanji, Gopal K. Statistical Tests, Sage,1993. LeviStrauss, C. Structural Anthropology; 6. Basic Books 1963. (Part 1 pp. 3791) Luckacs, George. History and Class Consciousness. Merlin Press, 1971. (Chapter 1) Margolis, Eric (ed), The Sage Handbook of Visual Research, Sage, 2011.
SOC752A	APPLIED STATISTICS FOR SOCIOLOGISTS AND OTHER SOCIAL SCIENTISTS	3-0-0-0-9	1. Styles of causal thought and models of controlled experiment: meaning of statistical inference concepts of relative error and confidence interval; simple bivariate approaches and unmatched differences; one way and factoria analysis of variance. 2. Causal analysis in nonexperimental data; conceptual framework as flowcharts. 3. Models and explanatory fit; modelling social phenomena; measures of life expectancy, disease burden and health inequality. 4. Analysis of frequencies chisquare, odds ratios and relative risk, Cramer’s V and Kendall; tau. 5.

			Multivariate analysis unstandardized and standardized regression coefficients; uses of dummy vaiables; role of proxies; structural equation models; analysing longitudinal and cohort data; tempo effects. 6. Standardized rates and ratios as dependent vairable; ratios of ratios and rates such as ratio of male and female mortality rates; working with indices such as HDI and PCI. Articles from journals: Americal Sociological Review, American Journal of Sociology, British Journal of Sociology, and Population and Development Review. **Course Reference**: 1. Emile Durkheim, Suicide: Studey in Sociology, The Free Press, New York, 1968 Book II, pp. 145294; 2. David C. Howell, Fundamental Statistics ofr Behavioral Sciences, Wadsworth, 2011; 3. Thomas J. Linneman, Social Statistics Routledge, 2011; 4. Jay Alan Weinstein, Applying Social Statistics: An Introduction to Quantitative Reasoning in Sociology, Rowman & Littlefield Publishers, Inc., 2010; 5. Lorena Madrigal, Statistics for Anthropology, Cambridge Press, 2012.
SOC799	PHD THESIS	----	Ph. D. Thesis

INDUSTRIAL AND MANAGEMENT ENGINEERING

INDUSTRIAL AND MANAGEMENT ENGINEERING

BT/BS-MT (Category – B) *(from other department)*					Template No. IME-1
	UG Requirements	PG Requirements			
C O U R S E S	1st to 6th	7th and 8th	Summer	9th	10th
	MSO201A [11]	DE PG-1 [09]*	IME697A [0]	M.Tech. Thesis [36]	M.Tech. Thesis [36]
		DE PG-2 [09]*			
		DE PG-3 [09]*			
		DE PG-4 [09]*			
		DE PG-5 [09]*			
		-			
		45	0	36	36

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Component : 45 Credits
Thesis Component : 72 Credits
Summer Internship : 0 Credits

REMARKS:

1) *The five DE PG courses should be selected form Basket – A. However, a student may be asked to take some MBA courses instead of IME courses as deemed fit by the IME DUGC and required by the thesis supervisor.
2) IME697A (summer internship) is mandatory.
3) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech. part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
4) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the parent department's BT programme requirements and counted towards PG requirements.

Basket – A

IME604A [09]
IME611A [09]
IME624A [09]
IME625A [09]
IME630A [09]
IME633A [09]
IME634A [09]
IME641A [09]
IME648A [09]
IME681A [09]
IME684A [09]
IME692A [09]

BT/BS – MBA (PG Part – Category C) (from other departments)				Template No. IME-2
C O U R S E S	SEMESTER			
	7th and 8th	Summer	9th	10th
	MBA601A [09]	MBA697 [0]	MBA699A-I [09]	MBA699A-II [09]
	DE MBA-1 [09]*		DE MBA-6 [09]	DE MBA-11 [09]
	DE MBA-2 [09]*		DE MBA-7 [09]	DE MBA-12 [09]
	DE MBA-3 [09]*		DE MBA-8 [09]	DE MBA-13 [09]
	DE MBA-4 [09]*		DE MBA-9 [09]	DE MBA-14 [09]
			DE MBA-10 [09]	DE MBA-15 [09]
	45	0	54	54

MINIMUM GRADUATION REQUIREMENT IN MBA PART:

PG Component : 153 Credits
Summer Internship : 0 Credits

REMARKS:

1) *DE MBA-1, 2, 3 & 4 to be selected form Basket – B.
2) MBA697A (summer internship) is mandatory.
3) In place of any of the DE MBA (6 to 15), a student may substitute an IME course in consultation with the IME DUGC.
4) Minimum graduation requirements mentioned under the dual degree template are only for the MBA part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
5) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the BT/BS-MBA dual degree programme. These will be waived from the parent department's BT programme requirements and counted towards PG requirements.

Basket – B

MBA606A [09]
MBA607A [09
MBA611A [09]
MBA616A [09]
MBA617A [09]
MBA631A [09]
MBA661A [09]

MINOR	Template No. IME-3
Title	
C O U R S E S	DE PG-1
	DE PG-2
	DE PG-3
	-
	27

REMARKS:

1) DE PG may be from IME or MBA courses.

DEPARTMENT OF IME

Courses ID	Course Title	Credits L-T-P-D-[C]	Content
IME602	PROBABILITY AND STATISTICS	3-0-0--4	Probability: Sample space, events and probability; Conditional probability and independence; Random variable (RV); Expectation, variance and higher moments; Some standard probability distributions; Functions of RVs; Jointly distributed RVs; Some multivariate distributions; Sum of RVs; Limit theorems.Statistics: Population and sample; Sampling distributions; Properties of point estimators; Maximum likelihood method; Interval estimation; Hypothesis testing; Some standard hypothesis tests; Analysis of variance; Simple linear regression; Multiple linear regression; Goodness of fit tests. **Course Reference**: 1.H.J. Larson, Introduction to Probability Theory and Statistical Inference, John Wiley & Sons; 2. R.V. Hogg, A.T. Craig, and J.W. McKean, Introduction to Mathematical Statistics, Pearson Education. 1)V.K. Rohatgi and A.K.Md.E. Saleh, An Introduction to Probability and Statistics, Wiley India Private Limited.2)R.J. Larsen and M.L. Marx, An Introduction to Mathematical Statistics and Its Applications, Pearson Education; 3.P.G. Hoel, S. Port, and S. Stone, Introduction to Probability Theory, Houghton Mifflin; 4.P.G. Hoel, S. Port, and S. Stone, Introduction to Statistical Theory, Houghton Mifflin; 5.W. Feller, An Introduction to Probability Theory and its Applications (Vol. 1 & 2), Wiley India Private Limited.6) A.M. Goon, M.K. Gupta, and B. Dasgupta, An Outline of Statistical Theory (Vol. 1 & 2), World Press Private Limited.7) A.M. Goon, M.K. Gupta, and B. Dasgupta, Fundamentals of Statistics (Vol. 1 & 2), World Press Private Limited.8)J.P. Romano and E.L. Lehmann, Testing Statistical Hypotheses, Springer (SIE).9)N.R. Draper and H. Smith, Applied Regression Analysis, Wiley India Private Limited.
IME602A	PROBABILITY AND STATISTICS	3-0-0-0-9	Probability: Sample space, events and probability; Conditional probability and independence; Random variable (RV); Expectation, variance and higher moments; Some standard probability distributions; Functions of RVs; Jointly distributed RVs; Some multivariate distributions; Sum of RVs; Limit theorems. Statistics: Population and sample; Sampling distributions; Properties of point estimators; Maximum likelihood method; Interval estimation; Hypothesis testing; Some standard hypothesis tests; Analysis of variance; Simple linear regression; Multiple linear regression; Goodness of fit tests. **Course Reference**: 1. H.J. Larson, Introduction to Probability Theory and Statistical Inference, John Wiley & Sons; 2. R.V. Hogg, A.T. Craig, and J.W. McKean, Introduction to Mathematical Statistics, Pearson Education. Course Reference : 1)V.K. Rohatgi and A.K.Md.E. Saleh, An Introduction to Probability and Statistics, Wiley India Private Limited.2)R.J. Larsen and M.L. Marx, An Introduction to Mathematical Statistics and Its Applications, Pearson Education; 3.P.G. Hoel,

			S. Port, and S. Stone, Introduction to Probability Theory, Houghton Mifflin; 4.P.G. Hoel, S. Port, and S. Stone, Introduction to Statistical Theory, Houghton Mifflin; 5. W. Feller, An Introduction to Probability Theory and its Applications (Vol. 1 & 2), Wiley India Private Limited; 6.A.M. Goon, M.K. Gupta, and B. Dasgupta, An Outline of Statistical Theory (Vol. 1 & 2), World Press Private Limited; 7.A.M. Goon, M.K. Gupta, and B. Dasgupta, Fundamentals of Statistics (Vol. 1 & 2), World Press Private Limited; 8. J.P. Romano and E.L. Lehmann, Testing Statistical Hypotheses, Springer (SIE); 9.N.R. Draper and H. Smith, Applied Regression Analysis, Wiley India Private Limited.
IME603	INTRODUCTION TO COMPUTING	2-0-3--4	Computing Computer Organization, Data Representation, Data Structures suchas Arrays, Stacks, Queues and Trees, Algorithms for Searching and Sorting, Complexity, File Processing, Structured Programming, Lab exercises on Data Structure, Algorithms and File Management using any appropriate programming language.
IME603A	INTRODUCTION TO COMPUTING	3-0-0-0-9	Computing Computer Organization, Data Representation, Data Structures suchas Arrays, Stacks, Queues and Trees, Algorithms for Searching and Sorting, Complexity, File Processing, Structured Programming, Lab exercises on DataStructure, Algorithms and File Management using any appropriate programming language.
IME605	OPERATIONS RESEARCH FOR MANAGEMENT	3-0-0--4	Introduction, Mathematical Modeling, Linear programming Formulation, solution procedures, Duality, Sensitivity, Applications, Network methods Max Flow, Mincost, Shortest path, Dynamic programming Sequential decisions, Principle of optimality, Applications Integer Programming Formulation, Nonlinear Programming Applications and solution methods.
IME605A	OPERATIONS RESEARCH FOR MANAGEMENT	3-0-0-0-9	Introduction, Mathematical Modeling, Linear programming Formulation, solution procedures, Duality, Sensitivity, Applications, Network methods Max Flow, Mincost, Shortest path, Dynamic programming Sequential decisions, Principle ofoptimality, Applications Integer Programming Formulation, Nonlinear Programming Applications and solution methods.
IME611	FINANCIAL ENGINEERING	3-0-0--4	Module 1 : Basic Elements of Financial Systems and Financial Management Fundamentals of Financial Systems and Domain Knowledge of Finacial Management Module 2 : Mathematical Background Introduction to Stochastic Calculus : Wiener processes and Itos lemma,Stochastic Differential Equations, Martingales and Measures Numerical procedures : Binomial & trinomial trees, Monte Carlo simulation;finite difference methodsModule 3 : Options and Futures Markets Forward and futures contracts : Basic definition, Differences betweenForwards & Futures, Futures & Forwards on Commodities & Currencies,Valuation of Futures, Interest Rate Futures. Swaps: Currency Swaps, Interest Rate Swaps Options: Definitions, Payoff Diagrams, General Arbitrage Relationships, The Binomial Method, Applications to Hedging & Speculating, Delta Hedging, Arbitraging mispriced Options, Pricing of Stock Options on Stock Indices, Currencies, and Futures.Module 4: Financial Risk Management Introduction: Different types of risk; approaches to risk management; history of bank regulation.

			Greek letters: Definitions and how they are used.
IME611A	FINANCIAL ENGINEERING	3-0-0-0-9	Module 1: Basic Elements of Financial Systems and Financial Management Fundamentals of Financial Systems and Domain Knowledge of FinacialManagement; Module 2: Mathematical Background Introduction to Stochastic Calculus : Wiener processes and Itos lemma,Stochastic Differential Equations, Martingales and Measures Numerical procedures : Binomial & trinomial trees, Monte Carlo simulation;finite difference methods; Module 3: Options and Futures Markets Forward and futures contracts: Basic definition, Differences betweenForwards & Futures, Futures & Forwards on Commodities & Currencies,Valuation of Futures, Interest Rate Futures. Swaps: Currency Swaps, Interest Rate Swaps Options: Definitions, Payoff Diagrams, General Arbitrage Relationships, The Binomial Method, Applications to Hedging & Speculating, Delta Hedging, Arbitraging mispriced Options, Pricing of Stock Options on Stock Indices, Currencies, and Futures; Module 4: Financial Risk Management Introduction: Different types of risk; approaches to risk management; history of bank regulation. Greek letters: Definitions and how they are used.
IME624	COMPUTER AIDED DECISION SYSTEMS	2-0-3--4	System Analysis: Information System Analysis and Design, Decision Support System, Database Management Systems, Query Languages, Emerging Areas like communication network distributed systems and knowledge-based systems, Simulation; Methodology Approaches Programming Considerations, Languages and Data Structures, Statistical Considerations, Validation, Simulation Languages, Applications.
IME624A	COMPUTER AIDED DECISION SYSTEMS	3-0-0-0-9	System Analysis: Information System Analysis and Design, Decision Support System, Database Management Systems, Query Languages, Emerging Areas like communication network distributed systems and knowledge-based systems, Simulation; Methodology Approaches Programming Considerations, Languages andData Structures, Statistical Considerations, Validation, Simulation Languages, Applications.
IME625	INDRODUCTION TO STOCHASTIC PROCESSES AND THEIR APPLICATIONS	3-0-0-0-4	a) Introduction to stochastic process, Random walks, Markov chains, Markovprocesses, poisson processb) Application of Stochastic processes in (i) Queueing Theory, (ii) Scheduling, (iii) Manufacturing (iii) Finace, (vi) Marketing, etc.
IME625A	INDRODUCTION TO STOCHASTIC PROCESSES AND THEIR APPLICATIONS	3-0-0-0-9	a) Introduction to stochastic process, Random walks, Markov chains, Markov processes, poisson processb) Application of Stochastic processes in (i) Queueing Theory, (ii) Scheduling, (iii) Manufacturing (iii) Finace, (vi) Marketing, etc.
IME634	MANAGEMENT DECISION ANALYSIS	3-0-0--4	Multiobjective decisions, Decisions under uncertainty, Statistical Decision Trees, Applications from Quality Control and Production Control.
IME634A	MANAGEMENT DECISION ANALYSIS	3-0-0-0-9	Multiobjective decisions, Decisions under uncertainty, Statistical Decision Trees, Applications from Quality Control and Production Control.
IME636	INTRODUCTION TO GAME THEORY	3-0-0-0-4	Description of Game Theory, Representation of games in extensive form, Normal form and Coalition form, Concept of

			preferences and utility, Introduction to solution concepts for normal form games, Description of different solution concepts: Dominance, Nash equilibrium, correlated equilibrium, applications; Static model of oligopoly, extensive form games of perfect and imperfect information, refinements of Nash equilibrium, finite and infinite horizon, alternating bargaining models, games with incomplete information; Bayesian games, Bayes Nash equilibrium as a solution concept, finitely and infinitely repeated game; Trigger strategies, mechanism design, Properties of mechanism and implementation
IME636A	INTRODUCTION TO GAME THEORY	3-0-0-0-9	Description of Game Theory, Representation of games in extensive form, Normal form and Coalition form, Concept of preferences and utility, Introduction to solution concepts for normal form games, Description of different solution concepts: Dominance, Nash equilibrium, correlated equilibrium, applications; Static model of oligopoly, extensive form games of perfect and imperfect information, refinements of Nash equilibrium, finite and infinite horizon, alternating bargaining models, games with incomplete information; Bayesian games, Bayes Nash equilibrium as a solution concept, finitely and infinitely repeated game; Trigger strategies, mechanism design, Properties of mechanism and implementation
IME637	ADVANCED DECISION MODELS	3-0-0-0-4	Review of linear and integer linear programming. Multistage decision models: Dynamic programming. Network flow problems: Shortest path, maximum flow and minimum cost flow problems; Network optimization. Multiobjective decision models: Analytic hierarchy and network processes. Nonlinear programming: Uncostrained optimization; Lagrangian relaxation and KKT conditions; Convex optimization; Search, gradient and penalty-based methods; Quadratic programming. Metaheauristics and their applications to combinatorial optimization problems such as scheduling and allocation problems. Stochastic decision models: Markov chains; Queues and queuing networks. **Course Reference:** 1. Katta G. Murty, Linear Programming, Wiley. Laurence A. Wolsey, Integer Programming, Wiley. Richard Bellman, Dynamic Programming, Dover. R.K. Ahuja, T.L. Magnanti, J.B. Orlin, Network Flows, Prentice Hall; 2. A. Ishizaka and P. Nemery, Multicriteria Decision Analysis, Wiley. Rangarajan K. Sundaram, A First Course in Optimization Theory, Cambridge. S. Boyd and L Vandenberghe, Convex Optimization, Cambridge. J. Nocedal, S.J. Wright, Numerical Optimization, Springer. ElGhazali Talbi, Metaheauristics: From design to implementation, Wiley; 3. Kalyanmoy Deb, Multiobjective Optimization Using Evolutionary Algorithms, Wiley. D. Gross, C.M. Harris, Fundamentals of Queueing Theory, Wiley; 4. Wayne L. Whinston, Operations Research: Applications and Algorithms. 25.09.14
IME637A	ADVANCED DECISION MODELS	3-0-0-0-9	Review of linear and integer linear programming. Multistage decision models: Dynamic programming. Network flow problems: Shortest path, maximum flow and minimum cost flow problems; Network optimization. Multiobjective decision models: Analytic hierarchy and network processes. Nonlinear programming: Uncostrained optimization; Lagrangian relaxation

			and KKT conditions; Convex optimization; Search, gradient and penalty-based methods; Quadratic programming. Metaheauristics and their applications to combinatorial optimization problems such as scheduling and allocation problems. Stochastic decision models: **Course Reference**:1. Markov chains; Queues and queuing networks. Katta G. Murty, Linear Programming, Wiley. Laurence A. Wolsey, Integer Programming, Wiley; 2. Richard Bellman, Dynamic Programming, Dover. R.K. Ahuja, T.L. Magnanti, J.B. Orlin, Network Flows, Prentice Hall. A. Ishizaka and P. Nemery, Multicriteria Decision Analysis, Wiley; 3. Rangarajan K. Sundaram, A First Course in Optimization Theory, Cambridge. S. Boyd and L Vandenberghe, Convex Optimization, Cambridge. J. Nocedal, S.J. Wright, Numerical Optimization, Springer. ElGhazali Talbi, Metaheauristics: From design to implementation, Wiley; 4. Kalyanmoy Deb, Multi objective Optimization Using Evolutionary Algorithms, Wiley; 5. D. Gross, C.M. Harris, Fundamentals of Queueing Theory, Wiley. Wayne L. Whinston, Operations Research: Applications and Algorithms. 25.09.14
IME639	ANALYTICS IN TRANSPORT AND TELECOM	3-0-0-0-4	Introduction. Commonality in modeling problems across Transport and Telecom Introduction to graph Theory Review of linear and integer linear programming Minimum Spanning Tree Problem Steiner Tree Problem Shortest Path Problem, Dijkstras algorithm, Bellman Ford Algorithm All Shortest Paths, Floyds algorithm, Applications Introduction to complexity theory and NPcompleteness Network Flow Models, Max Flow Min Cut Problem, Minimum Cost FlowsKnapsack Problem and applications Bin Packing and applications Vehicle Routing Problem. Large Scale Optimization, Column Generation, Hands on with CPLEXSet Covering/Partitioning/Packing Models and Applications. Traveling Salesman Problem with applicationsFixed Charge Transportation ProblemTelecom Network Design, Access Networks, Backbone Networks. Design of Survivable Networks. Graph Coloring Model and applications. Chinese Postman Problem with applications. **Course Reference**: 1.R.K. Ahuja, T.L. Magnanti, J.B. Orlin, Network Flows, Prentice HalloE. Lawler; 2. Combinatorial Optimization: Networks and Matroids, Dovero H.M. Salkin, K. Mathur Foundations of Integer Programming; 3. North Hollando W.L. Whinston, Operations Research: Applications and Algorithms, Cengage Learning.
IME639A	ANALYTICS IN TRANSPORT AND TELECOM	3-0-0-0-9	Introduction. Commonality in modeling problems across Transport and Telecom Introduction to graph Theory Review of linear and integer linear programming Minimum Spanning Tree Problem Steiner Tree Problem Shortest Path Problem, Dijkstras algorithm, Bellman Ford Algorithm All Shortest Paths, Floyds algorithm, Applications Introduction to complexity theory and NPcompleteness Network Flow Models, Max Flow Min Cut Problem, Minimum Cost FlowsKnapsack Problem and applicationsBin Packing and applications Vehicle Routing Problem Large Scale Optimization, Column Generation, Hands on with CPLEXSet Covering/Partitioning/Packing Models and Applications Traveling Salesman Problem with applications

			Fixed Charge Transportation ProblemTelecom Network Design, Access Networks, Backbone Networks. Design of Survivable NetworksGraph Coloring Model and applications. Chinese Postman Problem with applications. **Course Reference**: 1. K. Ahuja, T.L. Magnanti, J.B. Orlin, Network Flows, Prentice HalloE. Lawler, Combinatorial Optimization: Networks and Matroids, Dovero H.M. Salkin; 2. K. Mathur Foundations of Integer Programming, North Hollando W.L. Whinston; 3. Operations Research: Applications and Algorithms, Cengage Learning
IME640A	INFORMATION SYSTEMS THEORY	3-0-0-0-9	Introduction: Information and its characteristics including entropy, System and its characteristics. IS Cycle Theories: Delone and McLean's Success Model, Technology Acceptance Model, Unified Theory of Acceptance and Use of Technology, User Resistance Theories, Task Technology Fit Theory, Process Virtualization Theory, Theory of Deferred Action. Strategic and Economic Theories: Resource based view, Theory of Slack Resources, Portfolio Theory, Theory of Lemon Markets, Technology Organization Environment Framework, Porter's Competitive Forces Model, Business Value of IT, Diffusion of Innovations, Institutional Theory, A Multilevel Social Network Perspective, Agency Theory. Socio Psychological Theories: Actor network theory, Theory of Planned Behaviour, Structuration Theory. **Course Reference**: 1. Dwivedi, Y.K, Wade, M.R., & Schneberger, S.L. (2012) Information Systems Theory: Explaining and Predicting Our Digital Society, Vol 1. Springer 14-JUL-2015.
IME641	DESIGN OF PRODUCTION SYSTEMS	3-0-0--4	Production Systems: concepts and integrated view, Policy Decisions, Capacityplanning, Product development, Plant location, Plant layout, Materials handling, Assembly line balancing, Work design, Methods engineering, Human Factors engineering, Project Management and Network models, Recent trends
IME641A	DESIGN OF PRODUCTION SYSTEMS	3-0-0-0-9	Production Systems: concepts and integrated view, Policy Decisions, Capacity planning, Product development, Plant location, Plant layout, Materials handling, Assembly line balancing, Work design, Methods engineering, Human Factors engineering, Project Management and Network models, Recent trends
IME642	OPERATIONS MANAGEMENT	3-0-0--4	Overview of Manufacturing Planning and Control; Forecasting; Smoothing Methods, Time Series Analysis, Decomposition Methods. Auto regressive and BoxJenkins Models. Qualitative Models; Aggregate Production Planning, Master Production Scheduling. Capacity Planning. Demand Management. Scheduling; Performance Measures, Single Machine Models, Flow Shop and Job Shops, Dynamic Scheduling, Evaluation of Heuristics and Dispatching Rules.
IME642A	OPERATIONS MANAGEMENT	3-0-0-0-9	Overview of Manufacturing Planning and Control; Forecasting; Smoothing Methods, Time Series Analysis, Decomposition Methods. Autoregressive and Box Jenkins Models. Qualitative Models; Aggregate Production Planning, Master Production Scheduling. Capacity Planning. Demand Management.

			Scheduling; Performance Measures, Single Machine Models, Flow Shop and Job Shops, Dynamic Scheduling, Evaluation of Heuristics and Dispatching Rules.
IME671	SOFTWARE PROJECT MANAGEMENT	3-0-0--4	This course will cover the techniques for managing software projects. It isintended to give the students both knowledge about, and practical experience in, the design and development of production quality software. The techniques taught in the class will be applied to a substantial team project. Course's topics will be as follows: Software Process; Software Configuration Management, CMM Levels, Software Project Planning and Costing; Requirements Engineering; Software Project Design; Testing; Software Metrics; Quality, Software Project Management; Human Factor.
IME692	ADVANCED STATISTICAL METHODS FOR BUSINESS ANALYTICS	3-0-0-0-4	The course is designed to train students on understanding research problems and situations requiring multivariate approaches, selecting appropriate multivariate techniques of data analysis, interpreting the results of analysis, and applying the techniques to business and research problems. The course includes topics dealing with multiple noninter dependence techniques (such as Factor Analysis, Cluster Analysis, Multidimensional Scaling), multiple dependence techniques (such as Multiple Regression Analysis, Discriminant Analysis, Path analysis, Multivariate Analysis of Variance), and nonparametric techniques of data analysis.
IME692A	ADVANCED STATISTICAL METHODS FOR BUSINESS ANALYTICS	3-0-0-0-9	The course is designed to train students on understanding research problems and situations requiring multivariate approaches, selecting appropriate multivariate techniques of data analysis, interpreting the results of analysis, and applying the techniques to business and research problems. The course includes topics dealing with multiple noninterdependence techniques (such as Factor Analysis, Cluster Analysis, Multidimensional Scaling), multiple dependence techniques (such as Multiple Regression Analysis, Discriminant Analysis, Path analysis, Multivariate Analysis of Variance), and nonparametric techniques of data analysis.
IME697	INDUSTRIAL PROJECT	-0-0--0	A 6 to 8 weeks industrial project for M.Tech. students during the period intervening the II and III semesters on a problem of practical relevance completed in an industrial or service organization. The student will study, analyze and then solvethe problem and prepare its implementation details, under the supervision andguidance of an officer/executive of the host organization. On completion ofthe summer project the student will submit a written report and give a seminarto the IME Department.
IME698	SEMINAR	0-0-0--0	SEMINAR
IME698A	SEMINAR	0-0---0	SEMINAR
IME699	M TECH THESIS	-0-0--	M. Tech. Thesis
IME700	RESEARCH METHODOLOGY	3-0-0-0-4	Introduction to Social Science Research Perspective, Different Approaches to Social Research, Approaches to Theory Building, Sampling, Measurement Issues & Scale construction, Research Design, Qualitative Research, Experimental Research, Survey

			Research, Quantitative Data Analysis Techniques, Research Writing and Presentation, Research Evaluation and Critique, Issues in Current Research Practice.
IME700A	RESEARCH METHODOLOGY	3-0-0-0-9	Introduction to Social Science Research Perspective, Different Approaches to Social Research, Approaches to Theory Building, Sampling, Measurement Issues & Scale construction, Research Design, Qualitative Research, Experimental Research, Survey Research, Quantitative Data Analysis Techniques, Research Writing and Presentation, Research Evaluation and Critique, Issues in Current Research Practice.
IME797	INDEPENDENT STUDY	3-0-0-0-4	Market Efficiency, Capital Structure, Asset Pricing, Corporate Governance, PortfolioTheory, Financial Intermediation, Credit Risk Modeling & Market Microstructure 1. Ananth Madhavan, Market microstructure: A survey, Journal of Financial Markets, Volume 3, Issue 3, August 2000, Pages 2052582. Bhattacharya Sudipto & Thakor Anjan V; Contemporary Banking Theory; Journal ofFinancial Intermediation, Elsevier, vol. 3(1), pages 250, October; 3. Black, F., and M. Scholes (1973)., The Pricing of Options, and Corporate Liabilities, Journal of Political Economy, MayJune, 637659; 4. Burton G. Malkiel., The Efficient Market Hypothesis and Its Critics, Princeton University CEPS Working Paper No. 91 April 2003; 5. Coase, Ronald H. (1937). The Nature of the Firm, Economica, N.S. 4, 3864056. Eugene F. Fama, Random Walks in Stock Market Prices; 6. Financial Analysts Journal, September/October 1965 (reprinted JanuaryFebruary 1995); 7. Fama, E. F., 1970; 8. Efficient Capital Markets: A Review of Theory and Empirical work; Journal of Finance, 25, 383417. 24-DEC-14
IME797A	INDEPENDENT STUDY	3-0-0-0-9	Market Efficiency, Capital Structure, Asset Pricing, Corporate Governance, PortfolioTheory, Financial Intermediation, Credit Risk Modeling & Market Microstructure. **Course Reference**: 1. Ananth Madhavan, Market microstructure: A survey, Journal of Financial Markets, Volume 3, Issue 3, August 2000, Pages 2052582. Bhattacharya Sudipto & Thakor Anjan V., 1993; 2. Contemporary Banking Theory; Journal of Financial Intermediation, Elsevier, vol. 3(1), pages 250, October; 3. Black, F., and M. Scholes (1973)., The Pricing of Options, and Corporate Liabilities, Journal of Political Economy, MayJune, 637659; 4. Burton G. Malkiel., The Efficient Market Hypothesis and Its Critics, Princeton University CEPS Working Paper No. 91 April 2003; 5. Coase, Ronald H. (1937). The Nature of the Firm, Economica, N.S. 4, 386405; 6. Eugene F. Fama; Random Walks in Stock Market Prices; Financial Analysts Journal, September/October 1965 (reprinted JanuaryFebruary 1995); 7. Fama, E. F, 1970; Efficient Capital Markets: A Review of Theory and Empirical work; Journal of Finance, 25, 383417. 24-DEC-14
IME799	PHD THESIS	----	Ph. D. Thesis
MBA601	ACCOUNTING & FINANCE	3-0-0-0-4	Balance sheet, profit and loss concepts, accounting principles and mechanics, Inventory Valuation and Depreciation accounting, Ratio and Fund flow analysis. Introduction to cost Accounting. Various methods of cost determination and cost accounting systems such as activity-based costing systems and

			responsibilityaccounting. Use of costing systems in decision making. Extensive case studies will be employed in this course.
MBA601A	ACCOUNTING & FINANCE	3-0-0-1-10	1. Introduction: Forms of Organization & Corporate Reporting, Reporting Fundamentals & Financial Reporting; 2. Financial Accounting: Accounting Principles, Accounting Mechanics, Accounting Standards & Financial Statement Analysis; 3. Management Accounting: Cost Volume Profit (CVP) Analysis, Costing SystemsTools & Techniques, Activity Based Costing (ABC); 4. Corporate finance: The Time Value of Money, Valuation, Capital Budgeting, Capital Structure & Dividend Policy, Working Capital Management. **Course Reference**: 1. Williams et al., Financial and Managerial Accounting, Tata McGraw Hill; 2. Fundamentals of Financial management, J. Van Horne & J M Wachowicz; 3. Principles of Corporate Finance Brealey, Myers & Allen.
MBA606	ECONOMIC ANALYSIS FOR MANAGEMENT	3-0-0-0-4	Basic concepts in business economics, Economics of Market, Utility theory, Determination of Price, Production Function, Theories of Competition, Theoryof Supply and Demand, Micro Level Firm Behaviour, Market Structure and Price, Concept of GDP, Theories of Money Supply, theory of Macro Economics. National Income and domestic product. Keynesian theory of income determination, Monetary approach, Inflation, balance of Payments, Structure of Indian economy, Indian economic growth and development.
MBA606A	ECONOMIC ANALYSIS FOR MANAGEMENT	3-0-0-1-10	Basic concepts in business economics, Economics of Market, Utility theory, Determination of Price, Production Function, Theories of Competition, Theory of Supply and Demand, Micro Level Firm Behaviour, Market Structure and Price, Concept of GDP, Theories of Money Supply, theory of Macro Economics, National Income and domestic product. Keynesian theory of income determination, Monetary approach, Inflation, balance of Payments, Structure of Indian economy, Indian economic growth and development, Aggregate Supply and Demand, Game Theory, Factor Markets, Student Project (Field research & Data Interpretation based term projects).
MBA607	FINANCIAL MANAGEMENT	3-0-0--4	Fund and Cost Flow Analysis, Working Capital Management, Determination of capital structure of the firm, Cost of Capital, Capital asset pricing models, Leverages, Investment Analysis, Portfolio Management, Debt Management, Dividend Policy, Concept of Financial Strategy, Course will be based on casestudy and journal articles.
MBA607A	FINANCIAL MANAGEMENT	3-0-0-1-10	Fund and Cost Flow Analysis, Working Capital Management, Determination ofcapital structure of the firm, Cost of Capital, Capital asset pricing models, Leverages, Investment Analysis, Portfolio Management, Debt Management, Dividend Policy, Concept of Financial Strategy, Course will be based on casestudy and journal articles.
MBA610	INVESTMENT VALUATION AND REAL OPTIONS	3-0-0--4	Investment Valuation Estimating Cost of Equity and Cost of Capital, Option Pricing Theory, Option Pricing Applications in Valuation Real Options in Managerial Decision-Making Binomial Tree Method for Valuing Real Options, Option to Delay, Option to Expand Option to Abandon, Valuing Natural Resoures Using Real Options, Appraising Projects with Real Options.

MBA610A	INVESTMENT VALUATION AND REAL OPTIONS	3-0-0-1-10	Introduction to Valuation methods, Investment Valuation, Estimating Cost of Equity and Cost of Capital, Derivatives, Option Pricing Theory, Option Pricing Applications ain Valuation, Real Options in Managerial Decision Making, Binomial Tree Method for Valuing Real Options, Option to Delay, Option to Expand, Option to Abandon, Valuing Natural Resources Using Real Options, Mini Project Identifying Real Options in Practice, Appraising Projects with Real Options. **Course Reference**: 1.Damodaran, Ashwath (2002), Investment Valuation, (Second Edition), Wiley; 2.Broyles, Jack (2003), Financial Managemnt and Real Options, Wiley; 3.Mun, Johnathan (2005), Real Options Analysis: Tools and Techniques for Valuing Strategic Investment and Decisions, 2nd Edition, Wiley; 4.Schwartz, Eduardo S. & Trigeorgis, Lenos (eds.) (2001), Real Options and Investment Under Uncertainty, MIT.Copeland, Tom & Antikarov, Valdimir (2001), Real Options: A Practitioner's Guide, Textre. Selected Case Studies on Valuation and Real Options.
MBA611	ORGANIZATION STRUCTURE AND BEHAVIOUR	3-0-0-0-4	Introduction to Organizations, Organization Goals, Organizations and Markets, Organization Structures and Systems, Strategy, Structure & Technology, Organization Environment and Culture, Various Design Options, Power and Politics, Organization Conflict, Change and Restructuring, Growth and Evolution, Learning Organizations and organization Effectiveness, Service Organizations, Organizations as Networks.State ofart research papers and case studies will be used for the selected topics.
MBA611A	ORGANIZATION STRUCTURE AND DESIGN	3-0-0-1-10	Introduction to Organizations, Work motivation and Organization Goals, Organizations and Markets, Organization Structures and Systems, Strategy, Structure & Technology, Organization Environment and Culture, Various Design Options, Power and Politics, Organization Conflict, Change and Restructuring, Growth and Evolution, Employee empowerment, Learning Organizations and organization Effectiveness, Service Organizations, Organizations as Networks. State ofart research papers and case studies will be used for the selected topics, Student Project (Field research & Data Interpretation based term projects).
MBA616	HUMAN RESOURCE MANAGEMENT	3-0-0--4	Meaning of Work and Humans as Resource, Human Resource Planning and Selection, Motivation and Compensation Management, Performance Appraisal, Career Management, Training and HRD, Group Dynamics and Leadership, TradeUnions and Industrial Disputes, Public Policy and Collective Bargaining, DueProcess, Empowerment and Participation, Technology & HRM, Japanese HRM.
MBA616A	HUMAN RESOURCE MANAGEMENT	3-0-0-1-10	Meaning of Work and Humans as Resource, Human Resource Planning andSelection, Motivation and Compensation Management, Performance Appraisal, Career Management, Training and HRD, Group Dynamics and Leadership, Trade Unions and Industrial Disputes, Public Policy and Collective Bargaining, Due Process, Empowerment and Participation, Technology & HRM, Japanese HRM.
MBA617	SOCIAL, POLITICAL	3-0-0--4	Industrial revolution and industrialization, Political economy of

	AND LEGAL ENVIRON OF BUSINESS		underdevelopment, Sociology of development, Indian rural and urban society, Influence of religionand karma, Multiplicity of languages, cultures, castes, Feudalism, Work ethic, Constitution of India, Party system, Fundamental rights, Local self government, Directive principles of state policy, Welfare state and Civil society, Social stratification, Environmental issues and legislation, and social movements, Corporate social responsibility and business ethics, Judicial system, Businesslaw, Contract act, Arbitration, Companies Act, Sale of goods act, partnershipact, negotiable instruments act, Income tax Act, Environmental legislation.
MBA617A	SOCIO-POLITICAL AND ETHICAL ASPECTS OF BUSINESS	3-0-0-0-9	Industrial revolution and industrialization, Political economy of under development, Sociology of development, Indian rural and urban society, Influence of religion and karma, Multiplicity of languages, cultures, castes, Feudalism, Work ethic, Constitution of India, Party system, Fundamental rights, Local self government, Directive principles of state policy, Welfare state and Civil society, Social stratification, Environmental issues and legislation, and social movements, Corporate social responsibility and business ethics, Judicial system, Businesslaw, Contract act, Arbitration, Companies Act, Sale of goods act, partnershipact, negotiable instruments act, Income tax Act, Environmental legislation.
MBA618	GLOBALIZATION, STATE & CORPORATIONS	----4	Globalisation perhaps is one of the most debated and contested concept ofthe contemporary times. As we are living in an era of unprecedented economic political and social interconnections there is a need to reexamine our assumptions about social and econmic organization. The purpose of the course is to studythe concept of globalisation and develop a multifaceted understanding of it. The course will focus on the role of corporations as drives of the contemporary wave of globalisation. It would also examine the changing role of State, especially in the framework of state corporation relations, both in the context of the developed economies as well as the third world. Further it would attempt tosituate the significance of global institutions like the IMF and the WTO in the Corporation vs. State debate on the one hand and the tension between the interests of the developed countries and the third world on the other. The course proposes to develop a historical understanding of the present wave of globalisation by delving in to the evolution of capitalism from its early mercantilist phase, to the industrial phase and finallly to its present finance capitalism phase. Itwill also discuss the contradictions of globalisation prosperity vs. poverty growth vs. underdevelopment and the underlying reasons for the same. Finally, the coursewill endeavour to evaluate some alternate forms of globalisation which havethe possibility of going beyond the problems of the current form of globalisation. The course proposes to adopt a multi disciplinary approach in developing an understadnding of the dominant theories and concepts. The classroom discussions will be based primarily on appropriate case studies of various countries and corporations.
MBA621	MANAGERIAL COMMUNICATIONS	3-0-0-0-4	The Manager, Interpersonal Communication, Ongoing Communication Process andflow, Organizational Managerial

			Communication, Personal Language, use and Communication System, The Media and Tools of Communication Climate, Low Structure: One to One Communication, High Structure: One to One Communication, Meetings and Conferences, Interactional Presentation, Keys to Functional Writings, Formats for Business letters and Memos, Exposure to eCommunication, Planning and Producing Effective Business Reports, Business and Managerial Communication Research. There will be atleast one case/exercise in each class.
MBA621A	MANAGERIAL COMMUNICATION: STRATEGIES AND TACTICS	3-0-0-0-9	Communication Theory & Practice: What is communication? Why is it needed? When is it needed? How is it done? Theory and practical essentials of communication Context, Purpose, Participants, Message, Medium, Channel, Barriers & Filters, Noise (Internal/External). What, is Organizational Communication? What is Managerial Communication? What are the different levels of managerial communication? What is intrapersonal, interpersonal, group and mass communication fundamentals? When are they needed by managers in the context of acompany? Ongoing Communication Process and flow, Personal Language, use and Communication System, The Media and Tools of Communication Climate, Low Structure: One toOne Communication, High Structure: One to One Communication, Meetings and Conferences, Interactional Presentation, Keys to Functional Writings, Formats for Business letters andMemos, Exposure to eCommunication, Planning and Producing Effective Business Reports, Business and Managerial Communication Research. Module IL Oral presentations by every student to class representing unique contexts; written reports by every student representing unique contexts; Individual Learnings. Module HI. Solving 8 different cases that deal with unique corporate situations, such as crisis management, conflict resolution, and negotiation. Team Learnings
MBA622	MANUFACTURING STRATEGY	3-0-0-0-4	Product and factory life cycle, strategic dimensions of technology, characteristics of job shops and flow shops, learning curve effects, economies of scale, resolution of conflicts between manufacturing and marketing, concept of PWP, design of organization structure of manufacturing divisions, interactions of design department with manufacturing, marketing, service and purchasing. Concept of aligning of manufacturing and the corporate strategy.
MBA622A	MANUFACTURING STRATEGY	3-0-0-0-9	Product and factory life cycle, strategic dimensions of technology, characteristics of job shops and flow shops, learning curve effects, economies of scale, resolution of conflicts between manufacturing and marketing, concept of PWP, design of organization structure of manufacturing divisions, interactions of design department with manufacturing, marketing, service and purchasing. The concept of aligning of manufacturing and the corporate strategy.
MBA623	STRATEGIC MANAGEMENT	3-0-0-0-4	General Management Function, Introduction to the corporate strategy, concept of organizational purpose, environmental scanning and formulation of objectives, strategy for growth such as concentric growth and diversification, role of valuesin strategy

			formulation and evaluation, managing diversity and growth, choiceof organizational structure and designing control systems to support the implementation of the strategy. Role of implementation issues in strategy formulation. Impact of organizational culture, structure, systems in strategy implementation and Merger and Acquisitions.
MBA623A	STRATEGIC MANAGEMENT	3-0-0-0-10	General Management Function, Introduction to the corporate strategy, concept of organizational purpose, environmental scanning and formulation of objectives, strategy for growth such as concentric growth and diversification, role of valuesin strategy formulation and evaluation, managing diversity and growth, choiceof organizational structure and designing control systems to support the implementation of the strategy. Role of implementation issues in strategy formulation. Impact of organizational culture, structure, systems in strategy implementation and Merger and Acquisitions.
MBA624	CORPORATE INNOVATION & ENTERPRENEURSHIP	3-0-0-0-4	In the first module this course will take an applied approach to learn the imperatives of lateral thinking and accelerated innovation in large organizations under relentless pressure of discontinuity. It will explore integrative frameworkfor individuals, virtual teams, using CPC and other rapid development/deploymentIT tools for accelerating targeted innovation and new product concept to market processes. In the second module this course will develop from theories of entrepreneurship an applied approach for managing disruptive innovation to create new high growth businesses. The crafting approach to finance, operations and other entrepreneurial strategies, real time monitoring and adaptive control systemsfor small businesses and the role of clusters, community of practitioners forstrategic flexibility will be some of the emerging paradigms covered in this course.
MBA626	MANAGEMENT OF TECHNOLOGY	3-0-0--4	Policy Technology Choice: Linkage; National Technology Policies; Technology, Competition and Industrial Structure; formulating the technology strategy, Technology Development and Acquisition process; Managing Technologies, Technology in Indian Industries, Strategic R&D management and Technological Consortia; Licensing and joint Ventures, Managing Technology Spillovers; Justification of new technology; management accounting and technology; Integration of New with Old technology, Assimilation of Technology; Intellectual Property Rights and their Implications for Industry Policy and Technology Management.
MBA626A	MANAGEMENT OF TECHNOLOGY	3-0-0-0-9	Policy Technology Choice: Linkage; National Technology Policies; Technology, Competition and Industrial Structure; formulating the technology strategy, Technology Development and Acquisition process; Managing Technologies, Technology in Indian Industries, Strategic R&D management and Technological Consortia; Licensing and joint Ventures, Managing Technology Spillovers; Justification of new technology; management accounting and technology;Integration of New with Old technology, Assimilation of Technology; Intellectual Property Rights and their Implications for Industry Policy and Technology Management.

MBA628	INTERNATIONAL BUSINESS MANAGEMENT	3-0-0-0-4	This course is relevant to all executives who plan or operationalise business strategies across multiple countries for international marketing, international sourcing, or international ownership. It focuses on learning about the global business environment, strategic opportunities and competeness forinternationalising, design and marketing of appropriate products and services, and key aspects in operationalising the strategy through organization structure, human resource, international coordination and leadership. While, working towards these learning objectives, the course will maintain aclose proximity to some themes of particular interest. We shall invite frequentattention to businesses that originate or operate in India/Asia. We will also beconscious of Governance relationships of investors from developed countries that affect their businesses in less developed ones. Cultural patterns as well as the Regulatory environment in different countries will be a recurrent theme in our discussions. And, we shall be conscious of how organizations may, through business without borders, stretch their capacities, and develop new competences and relationships. Much, of the course will be through Case discussions. Country and product - based presentations will also be utilised for building specific understanding.
MBA628A	INTERNATIONAL BUSINESS MANAGEMENT	3-0-0-0-9	This course is relevant to all executives who plan or operationalise business strategies across multiple countries for international marketing, international sourcing, or international ownership. It focuses on learning about the global business environment, strategic opportunities and competeness for internationalising, design and marketing of appropriate products and services, and key aspects in operationalising the strategy through organization structure, human resource, international coordination and leadership. While, working towards these learning objectives, the course will maintain aclose proximity to some themes of particular interest. We shall invite frequent attention to businesses that originate or operate in India/Asia. We will also be conscious of Governance relationships of investors from developed countries that affect their businesses in less developed ones. Cultural patterns as well as the Regulatory environment in different countries will be a recurrent theme in our discussions. And, we shall be conscious of how organizations may, through business without borders, stretch their capacities, and develop new competences and relationships. Much, of the course will be through Case discussions. Country and product -based presentations will also be utilised for building specific understanding.
MBA629	MANAGEMENT IN A GLOBAL ECONOMY: AN INDIAN PERSPECTIVE	3-0-0--4	The purpose of this course is to acquaint students with the current global market trends, issues of global governance and emarging debates about new technologies and corporate ethics. The expectation is to add value in the making of student’s world views on economy and society and provide a conceptual framework for the managerial tasks of diagnosing predicting and responding to changes in the world economy.
MBA630	ECONOMICS OF BUSINESS POLICY	3-0-0-0-4	Intermationally, a lot of intergration is taking place between economic theory, particularly industrial organization theory and management sterategy theory. Onthe one hand, industrial

			organization theorists are trying to draw on real life management practices to develop never and more relavent theories. On the otherhand, management strategy theorists are coming to depend on industrial organization theory to provide a general framework for organizing the otherwiseincoherent mass of facts available to them. In, this context, Economics of Business Policy seeks to provide managementstudents an introduction to the interface between industrial organization theoryand strategic management theory. It uses the business related tenents of economics (old and new) to develop a coherent analytical basis for the formulation and evaluation of the external and internal strategies of the firm. This is truewith respect to both a firm's external market environment and its internalorganization. The course emphasizes practical managerial applications of topicsfrom industrial economics and strategy: economics of scale and scope, industry analysis market structure commitment dynamic competition entry/exit the econmics of competitive advantage incentives in firms internal labour marketsand executive remuneration.
MBA630A	ECONOMICS OF BUSINESS POLICY	3-0-0-0-9	Intermationally, a lot of intergration is taking place between economic theory, particularly industrial organization theory and management sterategy theory. Onthe one hand, industrial organization theorists are trying to draw on real life management practices to develop never and more relavent theories. On the otherhand, management strategy theorists are coming to depend on industrial organization theory to provide a general framework for organizing the otherwise incoherent mass of facts available to them. In, this context, Economics of Business Policy seeks to provide management students an introduction to the interface between industrial organization theoryand strategic management theory. It uses the business related tenents ofeconomics (old and new) to develop a coherent analytical basis for the formulation and evaluation of the external and internal strategies of the firm. This is truewith respect to both a firm's external market environment and its internal organization. The course emphasizes practical managerial applications of topics from industrial economics and strategy: economics of scale and scope, industry analysis market structure commitment dynamic competition entry/exit the econmics of competitive advantage incentives in firms internal labour markets and executive remuneration.
MBA631	MARKETING MANAGEMENT	3-0-0-0-4	Marketing Environment, Company analysis (strength, weaknesses, opportunitiesand threats), the concept of marketing mix., four Ps of marketing, and theconcept of marketing strategy. The concept of market segmentation and differentiation, product positioning and its applications in demand forecasting. Consumer-Behaviour and Marketing Research. International marketing. Marketing economy and public policy issues. Emarketing. In this course concepts will be elaborated by the use of cases and research papers.
MBA631A	MARKETING MANAGEMENT	3-0-0-1-10	Marketing Environment, Company analysis (strength, weaknesses, opportunities and threats), the concept of marketing mix., four Ps of marketing, and the concept of marketing strategy. The concept of market segmentation and

			differentiation, product positioning and its applications in demand forecasting, Consumer Behaviour and Marketing Research, International marketing, Marketing economy and public policy issues, Emarketing. In this course concepts will be elaborated by the use of cases and research papers, Brand Management, Marketing matrix, Assignment based on business databases (quantitative as well as qualitative), Student Project (Field research & Data Interpretation based term projects)
MBA632	E- MARKETING	3-0-0-0-4	Marketing Fundamentals (environment, competition, consumer behaviour segmentation, Targeting, and positioning, 4Ps product, price, promotion, place), Marketing strategy, Digital marketing Opportunities, EParadigm, Internet Networking, Enterprise Middleware, Right Enterprise Applications, operational challenges web sales and marketing, web services, ASP and other financial choices, Realtime Analytic, Frontline Access, Miscellaneous Emerging opportunities.
MBA633	MARKETING RESEARCH	3-0-0-0-4	Nature and scope of Marketing research: a. The marketing research process; b. Research design and Implementation. Data collection: a. Secondary sources of marketing data, b. Standardized sources, c. Information collection: qualitative and observational methods, d. Information from respondents, e. Attitude measurement, f. Experimentation, g. Sampling fundamentals. Data Analysis: a. Hypothesis testing: Basic concepts and tests of associations, b. Correlation regression analysis, c. Discriminant and Canonical analysis, d. Factor and cluster analysis, e. Multidimensional scaling and conjoint analysis, f. Presenting the results. Recent Trends: a. Social media for market research b. Bayesian methods for marketing research c. Agent based modeling.
MBA633A	MARKETING RESEARCH	3-0-0-1-10	Nature and scope of Marketing research: a. The marketing research process, b. Research design and Implementation. Data collection: a. Secondary sourcesof marketing data, b. Standardized sources, c. Information collection: qualitative and observational methods, d. Information from respondents, e. Attitude measurement, f. Experimentation, g. Sampling fundamentals. Data Analysis: a. Hypothesis testing: Basic concepts and tests of associations, b. Correlation regression analysis, c. Discriminant and Canonical analysis, d. Factor and cluster analysis, e. Multidimensional scaling and conjoint analysis, f. Presenting the results. Recent Trends: a. Social media for market research b. Bayesian methods for marketing research c. Agent based modeling.
MBA634	CONSUMER BEHAVIOUR	3-0-0-0-4	Consumers in the Market place: a. An introduction to Consumer Behaviour, Consumers as individuals: a. Perception, b. Learning and Memory, c. Motivation, Values and Involvement, d. Attitudes, e. Attitude change and PersuasiveCommunication, f. Self, Consumers as decision Markers: a. Individual decision Making, b. The Purchase Situation, Postpurchase Evaluation and Product Disposal, c. Group Influence, Opinion Leadership, d. Organizational andHousehold Decision Making, Consumers and Sub Cultures: a. Income and SocialClass, b. Ethic, Ratial and Religious Subcultures, Consumers and Cultures: a. Cultural Influences on Consumer Behaviour, b. Lifestyles and Global

			Culture, c. Sacred and Profane Consumption.
MBA634A	CONSUMER BEHAVIOUR	3-0-0-0-10	Consumers in the Market place: a. An introduction to Consumer Behaviour, Consumers as individuals: a. Perception, b. Learning and Memory, c. Motivation, Values and Involvement, d. Attitudes, e. Attitude change and Persuasive Communication, f. Self, Consumers as decision Markers: a. Individual decision Making, b. The Purchase Situation, Postpurchase Evaluation and Product Disposal, c. Group Influence, Opinion Leadership, d. Organizational and Household Decision Making, Consumers and Sub Cultures: a. Income and SocialClass, b. Ethic, Ratial and Religious Subcultures, Consumers and Cultures: a. Cultural Influences on Consumer Behaviour, b. Lifestyles and Global Culture, c. Sacred and Profane Consumption.
MBA635	MARKETING OF SERVICES	3-0-0--4	Service Businesses today are global from inception yet needs intricate localization. Managing on line and on demand multi tasking multiplexities makes Service Marketing challenging and a thriving area of academic pursuit. Hands on field investigation and service prototyping for problem-based learning, Extensive comtemporary research findings. Strategic Marketing of Services, Comtemporary issues, understanding Customer Requirements, expectations and complexities of Customer Behaiour in the service domain, Extended Marketing Mix and creating the Service Value Proportion Segmentation and Targeting of Services Positioning and Relationship Marketing. Service Delivery and Service Recovery, Service scapes, Service Quality, aligning Service Design and Standards, Service Pricing, Yield Management. KanoQFD and other models, Service dominant Logic and energing customer roles in multilayer networks of Services delivery. Besides a number of case studies there will be an extended term project for Case Building.
MBA635A	MARKETING OF SERVICES	3-0-0-1-10	Service Businesses today are global from inception yet needs intricate localization. Managing on line and on demand multi tasking multiplexities makes Service Marketing challenging and a thriving area of academic pursuit. Hands on field investigation and service prototyping for problem-based learning, Extensive comtemporary research findings. Strategic Marketing of Services, Comtemporary issues, understanding Customer Requirements, expectations and complexities of Customer Behaiour in the service domain, Extended Marketing Mix and creating the Service Value Proportion Segmentation and Targeting of Services Positioning and Relationship Marketing. Service Delivery and Service Recovery, Service scapes, Service Quality, aligning Service Design and Standards, Service Pricing, Yield Management. KanoQFD and other models, Service dominant Logic and energing customer roles in multilayer networks of Services delivery. Besides a number of case studies there will be an extended term project for Case Building.
MBA637	BUSINESS TO BUSINESS MARKETING	3-0-0-0-4	Business to Business Marketing encompasses those management activities that enable a supplier firm to understand, create, and deliver value to other businesses, governments, and/or institutional customers. Business to business marketing is also referred to as business market management an industrial marketing. In year past, the topical area applied largely to

			industrial manufacturing firms. Today, business to business marketing provides practical frameworks, concepts, and tools for organizations as diverse as management consulting firms, investment banks, software solutions providers, and integrated supply management operations, among many other leading-edge technology and service companies. As business to business marketing expands its scope and stature, this courseaims at reinvigorating training in marketing beyond the tired old, 4Ps plus industrial examples format. This course will emphasize the interrelatedness of concepts such as multifunctional teams, strategic alliance environmental sensitivity, interorganizational trust, organizational learning and adherence to ethical principles. Furthermore, with the advent of relationship and network theories, this course emphasises that business marketer must learn not only to create value, but also to equitably share value with customer firms. Understanding of business buying and marketing behaviour within the context of relationship/network theories is the central learning from this proposed elective. Given, this background, the overall objectives of this course are to create an understanding of the current stateofart of organizational buying behaviour and business to business marketing.
MBA637A	BUSINESS TO BUSINESS MARKETING	3-0-0-0-10	Business to Business Marketing encompasses those management activities that enable a supplier firm to understand, create, and deliver value to other businesses, governments, and/or institutional customers. Business to business marketing is also referred to as business market management an industrial marketing. In year past, the topical area applied largely to industrial manufacturing firms. Today, business to business marketing provides practical frameworks, concepts, and tools for organizations as diverse as management consulting firms, investment banks, software solutions providers, and integrated supply management operations, among many other leading-edge technology and service companies. As business to business marketing expands its scope and stature, this courseaims at reinvigorating training in marketing beyond the tired old, 4Ps plus industrial examples format. This course will emphasize the interrelatedness of concepts such as multifunctional teams, strategic alliance environmental sensitivity, interorganizational trust, organizational learning and adherence to ethical principles. Furthermore, with the advent of relationship and network theories, this course emphasises that business marketer must learn not onlyto create value, but also to equitably share value with customer firms. Understanding, of business buying and marketing behaviour within the contextof relationship/network theories is the central learning from this proposed elective. Given this background, the overall objectives of this course are to create an understanding of the current state-of-art of organizational buying behaviour andbusinesstobusiness marketing.
MBA639	STRATEGIC MARKETING-CONTEMPORARY ISSUES	3-0-0-0-4	Successful Marketing in highly competitive global markets of today needs break through concepts, socially responsible and innovative execution. And mastering that blend entails participatory, immersive learning. This, practice oriented course

			will be based on integrative and investigative projects to consolidate the learning from foundations courses. CoursePlan and Modules: 1. Market opportunity recognition and evaluation 2. Generating business models 3. Green and sustainable marketing scenarios 4. Contextual strategies for products, services & brands 5. Emerging perspectives on marketing practices and corporate reputation.
MBA639A	STRATEGIC MARKETING-CONTEMPORARY ISSUES	3-0-0-0-9	Successful Marketing in highly competitive global markets of today needs break through concepts, socially responsible and innovative execution. And mastering that blend entails participatory, immersive learning. This practice, oriented course will be based on integrative and investigative projects to consolidate the learning from foundations courses. Course Plan and Modules: 1. Market opportunity recognition and evaluation 2. Generating business models 3. Green and sustainable marketing scenarios 4. Contextual strategies for products, services & brands 5. Emerging, perspectives 14 on marketing practices and corporate reputation.
MBA640	INTELLECTUAL PROPERTY MANAGEMENT, VALUE CREATION AND VALUE CAPTURE	3-0-0-0-4	ModuleI: Intellectual Property Management. Market Capitalization, Intellectual Capital (IC), Components of Intellectual Capital, Tangible and Intangible Assets of Firms, Goodwill, Linkage between IC, Corporate Strategy, and Profits, Relationship between Intellectual Capital and Intellectual Property, Knowledge Economy and the need for Intellectual Property Management, Various Types of Intellectual Property trademarks, Copyrights, Patents, Trade Secrets, and Industrial Design, International IP Treaties/Agreements on IP Rights, Types of Patents, Patenting Advantage, Offensive and Defensive IP Strategies, Global Innovation Indexs and IP Management, Intellectual Property Strategies in Indian Context Universities, CSIR and Commercial Firms ModuleII: The Dynamics of Value Creation and Value Capture. Module III: Patent Mapping.
MBA640A	INTELLECTUAL PROPERTY MANAGEMENT, VALUE CREATION AND VALUE CAPTURE	3-0-0-1-10	ModuleI: Intellectual Property Management. Market Capitalization, Intellectual Capital (IC), Components of Intellectual Capital, Tangible and Intangible Assets of Firms, Goodwill, Linkage between IC, Corporate Strategy, and Profits, Relationship between Intellectual Capital and Intellectual Property, Knowledge Economy and the need for Intellectual Property Management, Various Types of Intellectual Property trademarks, Copyrights, Patents, Trade Secrets, and Industrial Design, International IP Treaties/Agreements on IP Rights, Types of Patents, Patenting Advantage, Offensive and Defensive IP Strategies, Global Innovation Indexs and IP Management, Intellectual Property Strategies in Indian Context Universities, CSIR and Commercial Firms ModuleII: The Dynamics of Value Creation and Value Capture. ModuleIII: Patent Mapping.
MBA641	COMPUTING FOR MANAGEMENT	3-0-0-0-4	Computers and Management Function, Introduction to an appropriate high-level language, Introduction to Data Structures, Computer Organization, System Configuration, Introduction to data base management, management information systems, decision support systems and simulation.

MBA641A	COMPUTING FOR MANAGEMENT	3-0-0-0-9	Computers and Management Function, Introduction to an appropriate high-level language, Introduction to Data Structures, Computer Organization, System Configuration, Introduction to data base management, management information systems, decision support systems and simulation.
MBA643	SIMULATION OF BUSINESS SYSTEMS	3-0-0-0-4	Simulation Philosophy and Methodologies, Review of Basic Probability and Statistics, Random number Generation, Programming Considerations, Languages and Data Structures, Verification and Validation, Simulation Languages, Animation, Design and Execution of Simulation Experiments, Applications: Case Flow and Risk Analysis by Simulation Using Spreadsheets, Simulation of Production System Inventories, Queues and Production Scheduling.
MBA643A	SIMULATION OF BUSINESS SYSTEMS	3-0-0-0-9	Simulation Philosophy and Methodologies, Review of Basic Probability and Statistics, Random number Generation, Programming Considerations, Languages and Data Structures, Verification and Validation, Simulation Languages, Animation, Design and Execution of Simulation Experiments, Applications: Case Flow and Risk Analysis by Simulation Using Spreadsheets, Simulation of Production System Inventories, Queues and Production Scheduling.
MBA645	MANAGEMENT INFORMATION SYSTEMS	3-0-0--4	Foundation Concepts: Basic information systems concepts about the components and the operations, managerial, and strategic roles of information systems; Technology: Major concepts, developments, and managerial implications involved in computer hardware, software, telecommunications and database management: technologies; Applications: How the Internet, intranets, extranets and other information technologies are used in modern information systems to support electronic commerce, enterprise collaboration, business operations, managerial decision making, and strategic advantage; Development: Developing information system solutions to business problems using a systems approach to problem solving and variety of business application development methodologies; Management: The challenges of managing information systems technologies,resources, and strategies, including global IT management, strategic IS planning and implementation, and security and ethical challenges. This course also includes case presentations/discussions along with a final term paper.
MBA645A	MANAGEMENT INFORMATION SYSTEMS	3-0-0-1-10	Foundation Concepts: Basic information systems concepts about the components and the operations, managerial, and strategic roles of information systems; Technology: Major concepts, developments, and managerial implications involved in computer hardware, software, telecommunications and database management: technologies; Applications: How the Internet, intranets, extranets and other information technologies are used in modern information systems to support electronic commerce, enterprise collaboration, business operations, managerial decision making, and strategic advantage; Development: Developing information system solutions to business problems using a systems approach to problem solving and variety of business application development

			methodologies; Management: The challenges of managing information systems technologies,resources, and strategies, including global IT management, strategic IS planning and implementation, and security and ethical challenges. This course also includes case presentations/discussions along with a final term paper.
MBA646	ENTERPRISE INTEGRATION WITH IT	3-0-0--4	Need for integration, Evolution of ERP, Components of ERP, Enterprise evaluation, Business process mapping, Business Process Reengineering, Understanding and evaluating ERP packages, Technology evaluation, Networking issues, ERP implementation, Human resource issues and change management, SAP system, Project on SAP system, Case studies
MBA646A	ENTERPRISE INTEGRATION WITH IT	3-0-0-0-9	Need for integration, Evolution of ERP, Components of ERP, Enterprise evaluation, Business process mapping, Business Process Reengineering, Understanding and evaluating ERP packages, Technology evaluation, Networking issues, ERP implementation, Human resource issues and change management, SAP system, Project on SAP system, Case studies
MBA647	BUSINESS PROCESS MANAGEMENT	3-0-0-0-4	Introduction to Business Process Management (BPM); History; Importance of improving business processes; Drivers and triggers of BPM; Stakeholders; Importance of organizational strategy and process architecture; Selling BPM technology; Critical success factors in a BPM project.Critical implementation aspects for a BPM solution; Importance of a structured approach to implementing BPM; The BPM implementation framework: Organizational strategy phase, process architecture phase, Launch pad phase, Understand phase, Innovate phase, People phase, Develop phase, Implement phase, Realize phase, Sustainable performance phase; Project management; People change management; Leadership. BPM maturity; Embedding BPM within the organization; Methods, tools and techniques of business process modelling, analysis and design.BPM Process Patterns: Basic control patterns, Advanced branching and synchronization patterns, Structural patterns, Multiple instance patterns, State based patterns, cancellation patterns; Business Process Languages.Best practices in BPM; BPM in eBusiness, eCommerce and eGovernment; BPM case studies.
MBA647A	BUSINESS PROCESS MANAGEMENT	3-0-0-0-9	Introduction to Business Process Management (BPM); History; Importance of improving business processes; Drivers and triggers of BPM; Stakeholders; Importance of organizational strategy and process architecture; Selling BPM technology; Critical success factors in a BPM project.Critical implementation aspects for a BPM solution; Importance of a structured approach to implementing BPM; The BPM implementation framework:Organizational strategy phase, process architecture phase, Launch pad phase, Understand phase, Innovate phase, People phase, Develop phase, Implement phase, Realize phase, Sustainable performance phase; Project management; People change management; Leadership.BPM maturity; Embedding BPM within the organization; Methods, tools and techniques of business process modelling, analysis and

			design.BPM Process Patterns: Basic control patterns, Advanced branching and synchronization patterns, Structural patterns, Multiple instance patterns, State based patterns, cancellation patterns; Business Process Languages.Best practices in BPM; BPM in eBusiness, eCommerce and eGovernment; BPM case studies.
MBA648	SOFTWARE QUALITY MANAGEMENT	3-0-0-0-4	Introduction, Software Quality Practices, Software Quality Benchmarks, Software Quality Economics, Software Quality and the Cost of Ownership, Software Quality and the Cost to Developers, Software Quality and Profitability, Calculating Return on Investment Software Product Quality, Role of Metrics in Software Quality, Software Quality Attributes, Software Reliability, Software Maintenance, Software Reuse, Software Verification and Validation, Software Inspections: Effectiveness and Efficiency, Unit Analysis and Testing, Intellectual Property Protection for Software Software Process Quality: Need, Models and Frameworks, Structure, Classification, Automation, Improvement, Measuring Software Process, Software Development Process Audits, Agile Software Development Quality Assurance, Agile & Iterative Software Development, Agile Software Methods: State of the Art Requirements Specification using User Stories in Agile Software Development, Handling of Software Quality Defects in Agile Software Development, Agile Quality Assurance Techniques for GUI Based Applications, Software Configuration Management in Agile Software Development, 17 Improving Quality by Exploiting Human Dynamics in Agile Methods, Software Quality and Culture, Sustaining Quality, Software Technical Review Process, Case Studies
MBA649	E -COMMERCE	3-0-0-0-4	eBusiness Models, Building; ecommerce infrastructure, eBusiness challenges, Supplychain, Data exchange standards, Returns, Customer Service, ePayments, security and frauds, Outsourcing, Laws pertaining to ecommerce.
MBA649A	E -COMMERCE	3-0-0-0-9	eBusiness Models, Building; ecommerce infrastructure, eBusiness challenges, Supplychain, Data exchange standards, Returns, Customer Service, ePayments, security and frauds, Outsourcing, Laws pertaining to ecommerce.
MBA651	QUANTITATIVE METHODS FOR DECISION MAKING	3-0-0-0-4	Introduction to decision analysis and process. Elementary probability theory, conditional probability, Bayesian decision analysis, EVPI, moment generating functions, the central limit theorem, Descriptive and deductive statistics, Hypothesis testing and Regression
MBA651A	QUANTITATIVE METHODS FOR DECISION MAKING	3-0-0-1-10	Introduction to decision analysis and process, Simplex Method, Duality Theory, Network Problems, Elementary probability theory, Decision Sciences, EVPI, random variables, probability distributions, conditional probability, Bayes theorem, moment generating functions, central limit theorem, Descriptive and deductive statistics, Sampling techniques, Estimation, Hypothesis testing and Regression (linear and nonlinear), Student Project (Field research & Data Interpretation based term projects)
MBA652	STATISTICAL MODELLING FOR	3-0-0-0-4	Economic questions and data, Review of probability, Review of statistics, Linear regression with one regressor, Hypothesis tests

	BUSINESS ANALYTICS		and confidence intervals for ain simple regression, Linear regression with multiple regressors, Hypothesis tests and confidence intervals in multiple regression, Nonlinear regression functions, Regression with binary dependent variable, Regression with panel data, Introduction to Time Series Regression and Forecasting. Estimation of Dynamic Causal Effects, Additional topics in Time Series Regression (VAR, ARCH, GARCH).
MBA652A	STATISTICAL MODELLING FOR BUSINESS ANALYTICS	3-0-0-1-10	Economic questions and data, Review of probability, Review of statistics, Linear regression with one regressor, Hypothesis tests and confidence intervals for ain simple regression, Linear regression with multiple regressors, Hypothesis tests and confidence intervals in multiple regression, Nonlinear regression functions, Regression with binary dependent variable, Regression with panel data, Introduction to Time Series Regression and Forecasting. Estimation of Dynamic Causal Effects, Additional topics in Time Series Regression (VAR, ARCH, GARCH).
MBA654	INNOVATION FOR SUSTAINABLE BUSINESS ADVANTAGE	3-0-0-0-4	ModuleI: Innovation Concepts and Principles. Historical Perspectives, Innovation Myths and Realities, Challenges, Triggers and Sources for Creativity and Innovation, Innovation by individuals, communities and Corporations, Innovators Profile, Innovation Cycle, Phases of Innovation Cycle, Differences between Structured and Unstructured Innovation, Link between Corporate Vision, Strategy and Innovation, Components of Strategic Innovation, Organizational Architecture for Strategic Innovation, The Role of Government Policy in Innovation, The Roles of Venture Capitalists and Business Angels in Innovation, Eight Barriers to Innovation, Twelve Principles for Breaking Innovation Barriers, Innovation Principles for Sustainable Competitive Advantage and Generation of Wealth and Value ModuleII: Innovation Approaches and Frameworks. Incremental, Breakthrough and Disruptive Innovation, Design based Innovation, Open vs. Closed Innovation; Kotlers Four Levels of Innovation: Business Model Innovation, Process Innovation, Market Innovation and Product/Service Innovation; Innovation Frameworks: Hansen Birkinshaw, Tracy Wiersema, Sawhney Wolcott; Reverse Innovation, Essential Principles and Practice of Reverse Innovation, Changing the Mind and the Management Model; Jugad Innovation, Essential Principles and Practice of Jugad Innovation, Jugad Innovations Future for Emerging Markets, Illustrative commercial examples for Innovation ModuleIII: Innovation Project. A practical project that illustrates the Innovation principles
MBA654A	INNOVATION FOR SUSTAINABLE BUSINESS ADVANTAGE	3-0-0-0-9	ModuleI: Innovation Concepts and Principles. Historical Perspectives, Innovation Myths and Realities, Challenges, Triggers and Sources for Creativity and Innovation, Innovation by individuals, communities and Corporations, Innovators Profile, Innovation Cycle, Phases of Innovation Cycle, Differences between Structured and Unstructured Innovation, Link between Corporate Vision, Strategy and Innovation, Components of Strategic Innovation, Organizational Architecture for Strategic Innovation, The Role of Government Policy in

			Innovation, The Roles of Venture Capitalists and Business Angels in Innovation, Eight Barriers to Innovation, Twelve Principles for Breaking Innovation Barriers, Innovation Principles for Sustainable Competitive Advantage and Generation of Wealth and ValueModuleII: Innovation Approaches and Frameworks. Incremental, Break through and Disruptive Innovation, Design based Innovation, Open vs. Closed Innovation; Kotlers Four Levels of Innovation: Business Model Innovation, Process Innovation, Market Innovation and Product/Service Innovation; Innovation Frameworks: Hansen Birkinshaw, Tracy Wiersema, Sawhney Wolcott; Reverse Innovation, Essential Principles and Practice of Reverse Innovation, Changing the Mind and the Management Model; Jugad Innovation, Essential Principles and Practice of Jugad Innovation, Jugad Innovations Future for Emerging Markets, Illustrative commercial examples for InnovationModuleIII: Innovation Project. A practical project that illustrates the Innovation principles
MBA661	PRODUCTION AND OPERATIONS MANAGEMENT	3-0-0-1-4	Concepts, Context and decision process in production system; Policy, product and process decisions; Forecasting methods; Product design and process selection; Theory of constraints; Value analysis. Facilities location and layout; Capacity planning; Line balancing; Learning curves, Production planning; Aggregate planning; Lot sizing; Product scheduling. Inventory Management: Inventory costs; EOQ model; Stochastic models and safety stock. Integration; MRP and ERP; Supply chain concepts; JIT and Kanban systems. Quality control; Project management; Managing waiting lines. **Course Reference**: 1. S. Nahmias; Production and Operations Analysis; McGraw Hill; 2. Cachon and Terwiesch; Matching Supply with Demand; McGraw Hill; 3. W. Stevenson; Operations Management; McGraw Hill.
MBA661A	PRODUCTION AND OPERATIONS MANAGEMENT	3-0-0-1-10	Concepts, Context and decision process in production system; Policy, product and process decisions; Forecasting methods; Product design and process selection; Theory of constraints; Value analysis. Facilities location and layout; Capacity planning; Line balancing; Learning curves, Production planning; Aggregate planning; Lot sizing; Product scheduling. Inventory Management: Inventory costs; EOQ model; Stochastic models and safety stock. Integration; MRP and ERP; Supply chain concepts; JIT and Kanban systems. Quality control; Project management; Managing waiting lines. **Course Reference**: 1. S. Nahmias; Production and Operations Analysis; McGraw Hill; 2. Cachon and Terwiesch; Matching Supply with Demand; McGraw Hill; 3. W. Stevenson; Operations Management; McGraw Hill.
MBA663	TOTAL QUALITY MANAGEMENT	3-0-0--4	Total Quality Management, quality management Philosophies, Leadership, Employee involvement and customer Value Evaluation, Kaizin, Problem Solving and Quality Management, problem solving Fundamentals, Problem Identification, Definition, Diagnosis, Alternative Generation and Evaluation, Elementry concepts relatedto 7 Old and 7 New Tools for quality Assurance, Basic Statistical Concepts, Controlof Accuracy and Precision, Process Capability, SPC, Acceptance Sampling,

			MILSTD105D. Quality Management Systems, ISO 9000, Quality Engineering, QualityFunction Development, Introduction to Design of Experiments, Process Optimization and Robust Product Design, Steps to Six Sigma, Management of Service Quality,Management of Software Quality, Course will include projects and industry casestudies.
MBA663A	TOTAL QUALITY MANAGEMENT	3-0-0-1-10	Total Quality Management, quality management Philosophies, Leadership, Employe einvolvement and customer Value Evaluation, Kaizin, Problem Solving and Quality Management, problem solving Fundamentals, Problem Identification, Definition, Diagnosis, Alternative Generation and Evaluation, Elementry concepts relatedto 7 Old and 7 New Tools for quality Assurance, Basic Statistical Concepts, Controlof Accuracy and Precision, Process Capability, SPC, Process Control Charts, Acceptance Sampling, MILSTD105D. Quality Management Systems, ISO 9000, Quality Engineering, QualityFunction Development, Introduction to Design of Experiments, Process Optimizationand Robust Product Design, Steps to Six Sigma, Management of Service Quality, SERVQUAL, Management of Software Quality, Course will include live industry projects and industry case studies.
MBA664	SUPPLY CHAIN MANAGEMENT	3-0-0-0-4	Strategic Framework for Supply Chain, Materials Management Functions, Forecasting and market Analysis, Purchasing and Procurement, Physical Supply, Managing Inventories, MRP and Capacity Planning, Inventory Valuation, Logistical Management Materials Handling, Warehousing/ Storage and Retrieval, Transportation and Distribution, IT and Role of EBusiness, Financial Evaluation.
MBA664A	SUPPLY CHAIN MANAGEMENT	3-0-0-0-10	Strategic Framework for Supply Chain, Materials Management Functions, Forecasting and market Analysis, Purchasing and Procurement, Physical Supply, Managing Inventories, MRP and Capacity Planning, Inventory Valuation, Logistical Management Materials Handling, Warehousing/ Storage and Retrieval, Transportation and Distribution, IT and Role of EBusiness, Financial Evaluation.
MBA665	MANUFACTURING PLANNING AND CONTROL	3-0-0-0-4	Framework of Manufacturing Planning, Forecasting Models, Hierarchical Planning System, Facility Location and Layout, Resource Scheduling, Flexible Manufacturing analysis, design and Planning, JustinTime Manufacturing, Simulation and Performance Evaluation, Lean and Agile Manufacturing.
MBA665A	MANUFACTURING PLANNING AND CONTROL	3-0-0-0-9	Framework of Manufacturing Planning, Forecasting Models, Hierarchical Planning System, Facility Location and Layout, Resource Scheduling, Flexible Manufacturing analysis, design and Planning, JustinTime Manufacturing, Simulation and Performance Evaluation, Lean and Agile Manufacturing.
MBA666	PROJECT MANAGEMENT	3-0-0-0-4	Characteristics of Projects, Project Economics, Screening and Selection, Evaluation, Structuring Organizational and Work Breakdown, Scheduling, Budgeting, Resource Management, Life Cycle Costing, Project Control, R&D Projects, Computer Supports, Project Termination. Agile Project Management, Privacy and Security. Agile Project Management, Privacy and Security. John Nicholas and Herman Steyn: Project Management for Engineering, Business and Technology,

			Routledge Taylor and Francis Group, Fourth Edition, Indian Special Edition.
MBA666A	PROJECT MANAGEMENT	3-0-0-1-10	Characteristics of Projects, Project Economics, Screening and Selection, Evaluation, Structuring Organizational and Work Breakdown, Scheduling, Budgeting, Resource Management, Life Cycle Costing, Project Control, R&D Projects, Computer Supports, Project Termination. Agile Project Management, Privacy and Security. Agile Project Management, Privacy and Security. John Nicholas and Herman Steyn: Project Management for Engineering, Business and Technology, Routledge Taylor and Francis Group, Fourth Edition, Indian Special Edition.
MBA671	MANAGING SERVICE OPERATIONS	3-0-0-0-4	Service as Product, Design of Service Systems, Location and Layout of Service Facilities, Service Engineering including Work Design, Human Factors, Automation and Communication, Productivity and Service Effectiveness, Network Planning including Queuing Networks, Manpower and Resource Scheduling and Distribution Planning. Professional Service: Achieving differentiation through knowledge and relationship, Service and Competitive Strategy; Service delivery systems and IT applications; IT enabled services and Technology Convergence; Managing for World Class; Service Quality and Service Level best practices for call centersand related services, Cross Cultural issues; Pricing and Transfer Pricing of Connected Services, Project Implementation, Learning, Innovation and Knowledge Management in the Service based business.
MBA671A	MANAGING SERVICE OPERATIONS	3-0-0-0-10	Service as Product, Design of Service Systems, Location and Layout of Service Facilities, Service Engineering including Work Design, Human Factors, Automation and Communication, Productivity and Service Effectiveness, Network Planning including Queuing Networks, Manpower and Resource Scheduling and Distribution Planning. Professional Service: Achieving differentiation through knowledge and relationship, Service and Competitive Strategy; Service delivery systems and IT applications; IT enabled services and Technology Convergence; Managing for World Class; Service Quality and Service Level best practices for call centersand related services, Cross Cultural issues; Pricing and Transfer Pricing ofConnected Services, Project Implementation, Learning, Innovation and Knowledge Management in the Service based business.
MBA675	INFRASTRUCTURE REGULATION, POLICY & FINANCE	3-0-0-0-4	Role of Infrastructure in Economic Development, Natural Monopoly and Economicsof Infrastructure Regulation, Rate of Return Regulation, Performance Based Regulation, Pricing for Infrastructure Sector, Role of Subsidies, Reforms in the Infrastructure Sector (Power, Telecom, Roads, Ports, Urban Services) Restructuring and Privatisation in Infrastructure Sector, Reform Acts, Competition in Infrastructure Sector (Bulk Power, Telecom, Transportation), Issues in Infrastructure Finance, Modes of Project Financing, Risks in Infrastructure Sector, Development of Infrastructure Projects BOO, BOOT, BOLT etc.
MBA675A	INFRASTRUCTURE REGULATION,	3-0-0-0-9	Role of Infrastructure in Economic Development, Natural Monopoly and Economics of Infrastructure Regulation, Rate of

	POLICY & FINANCE		Return Regulation, Performance Based Regulation, Pricing for Infrastructure Sector, Role of Subsidies, Reforms in the Infrastructure Sector (Power, Telecom, Roads, Ports, Urban Services) Restructuring and Privatisation in Infrastructure Sector, Reform Acts, Competition in Infrastructure Sector (Bulk Power, Telecom, Transportation), Issues in Infrastructure Finance, Modes of Project Financing, Risks in Infrastructure Sector, Development of Infrastructure Projects BOO, BOOT, BOLT etc.
MBA676	SECURITY ANALYSIS, DERIVATIVES & PORTFOLIO MANAGEMENT	3-0-0--4	Financial Markets, Investment Alternatives, Risk and Return, Portfolio Theory and Capital Asset Pricing, Capital Asset Pricing Theory and Arbitrate PricingTheory, Efficient Market Hypothesis, Security Analysis and Valuation, Valuation of equity and Fixed income securities, Fundamental Analysis, Technical Analysis, Investment Strategies, Derivatives, Options, Futures, Swaps, Black Scholes model, Value at risk, estimating volatility and correlations, Hedging and Portfolio Management.
MBA676A	SECURITY ANALYSIS, DERIVATIVES & PORTFOLIO MANAGEMENT	3-0-0-0-9	Financial Markets, Investment Alternatives, Risk and Return, Portfolio Theory and Capital Asset Pricing, Capital Asset Pricing Theory and Arbitrate Pricing Theory, Efficient Market Hypothesis, Security Analysis and Valuation, Valuation of equity and Fixed income securities, Fundamental Analysis, Technical Analysis, Investment Strategies, Derivatives, Options, Futures, Swaps, BlackScholesmodel, Value at risk, Estimating, volatility and correlations, Hedging and Portfolio Management.
MBA677	PROJECT FINANCING & MANAGEMENT	3-0-0--4	Generation and Screening of Project Ideas, Project Appraisal and Evaluation, Financial Projections, Investment Criteria, Cost Benefit Analysis, Project Finance, Financing Infrastructure Projects, Sources of Finance, Multilateral Project Financing, Consortium Financing, Venture Capital, Risk Analysis, Project LifeCycle, Techniques for Project Management.
MBA677A	PROJECT FINANCING & MANAGEMENT	3-0-0-0-10	Generation and Screening of Project Ideas, Project Appraisal and Evaluation, Financial Projections, Investment Criteria, Cost Benefit Analysis, Project Finance, Financing Infrastructure Projects, Sources of Finance, Multilateral ProjectFinancing, Consortium Financing, Venture Capital, Risk Analysis, Project LifeCycle, Techniques for Project Management.
MBA678	MANAGEMENT OF RISK IN FINANCIAL SYSTEM	3-0-0--4	Concept of Risk and Risk Management., Different types of Risks like Systematic Risk, Interest Rate Risk, Liquidity Risk, Operational Risk, Regulatory Risk, Market Risk, Foreign Exchange Risk, Commodity Price Risk, Industry Concentration Risk, Environmental Risk, Counter party Risk, Credit Risk, Legal Risk, Regulatory Risk etc. Methods of identifying and measuring different types of risks. Useof Risk Models. Methods of Risk control and Management, i.e., requirement of active Risk Management techniques through use of VaR model; monitoringof ALM (Asset Liability Management); use of derivatives like currency swaps, interest rate futures, forward rate agreements etc.

MBA678A	MANAGEMENT OF RISK IN FINANCIAL SYSTEM	3-0-0-0-9	Concept of Risk and Risk Management., Different types of Risks like Systematic Risk, Interest Rate Risk, Liquidity Risk, Operational Risk, Regulatory Risk, Market Risk, Foreign Exchange Risk, Commodity Price Risk, Industry Concentration Risk, Environmental Risk, Counter party Risk, Credit Risk, Legal Risk, Regulatory Risk etc. Methods of identifying and measuring different types of risks. Useof Risk Models. Methods of Risk control and Management, i.e., requirement of active Risk Management techniques through use of VaR model; monitoringof ALM (Asset Liability Management); use of derivatives like currency swaps, interest rate futures, forward rate agreements etc.
MBA679	COMMERCIAL BANKING, RISK MODELING AND RISK MANAGEMENT	3-0-0-0-4	The course will deal with the theory, tools and techniques necessary for efficient modeling and management of risk in financial services with emphasis on commercial banking. At the macro level emphasis is placed on the effect of regulatory and country specific factors on the functioning and the adherent risk in the operation of a commercial bank. At the micro level various facets of risk management which include interest rate, credit and market risk are covered in sufficient depth. The course also covers related topics in derivative pricing and hedging and application of option valuation models in modeling and managing the above risk. The course does not have a specific text book and consists of prescribed readings provided by the instructor.
MBA679A	COMMERCIAL BANKING, RISK MODELING AND RISK MANAGEMENT	3-0-0-0-10	The course will deal with the theory, tools and techniques necessary for efficient modeling and management of risk in financial services with emphasis on commercial banking. At the macro level emphasis is placed on the effect of regulatory and country specific factors on the functioning and the adherent risk in the operation of a commercial bank. At the micro level various facets of risk management which include interest rate, credit and market risk are covered in sufficient depth. The course also covers related topics in derivative pricing and hedging and application of option valuation models in modeling and managing the above risk. The course does not have a specific text book and consists of prescribed readings provided by the instructor.
MBA681	ENERGY AND CARBON MARKETS: ECONOMICS, POLICY AND REGULATION	3-0-0-0-4	Energy and Economic Development: National and International Perspective, Structure of Energy Demand and Supply,, Energy Value Chain and Energy Accounting, India Energy Scenario 2047, Economics of Energy and Exhaustible Resources , Energy Security, Energy Policy and Planning, Modelling for Energy Markets: Applications in General Algaebric Modelling System (GAMS), International Markets for Energy: Oil, Coal, Natural Gas and Uranium, Indian Energy Markets: Oil & Gas, Coal and Electricity, Private Investment in Energy Sectors: NELP, Coal Policy, Power Policy, Regulation of Indian Energy Sectors Electricity, Oil & Gas and Coal Sectors, Pricing in Energy Markets: Electricity, Coal, Oil and Natural Gas, Functioning of Power Exchange and Commodity Exchanges (Energy), Cross Border Energy Cooperation, Energy and Environment, Climate Change, UNFCC, Kyoto Protocol and

			beyond, Clean Development Mechanism and its Process, International Carbon Markets and Carbon Finance, National Action Plan on Climate Change, JNN National Solar Mission, Renewable Energy: Technology, Economics and Policy, Market for Renewable Energy Certificates, Energy Conservation, Market for Energy Efficiency: ESCO and Market for Ecerts (White Certificates). One project work on relevant topic. **Course Reference**: 1. Environmental and Natural Resource Economics, Tom Tietenberg, AddisonWesley, 2000; 2. International Energy Markets: Understanding Pricing, Policies, and Profits, Carol Dahl, Penn Well Books, ISBN: 9780878147991, 2004; 3. Energy Efficiency: Principles and Practices, Penni McLeanConner, ISBN: 9781593701789, 2009; 4. Economics of Regulation and Antitrust Viscusi, Vernon & Harrington, MIT Press, 2000; 5. Integrated Energy Policy, Report of the Expert Committee, Govt. of India, Planning Commission, New Delhi, August 2006; 6. Relevant Publications of World Energy Council and International Energy Agency, World Bank and Asian Development Bank; 7. Relevant reports of respective Ministries; 8. Other relevant journal articles, reports, policy documents, regulations of regulatory commissions, case studies and class notes.
MBA681A	ENERGY AND CARBON MARKETS: ECONOMICS, POLICY AND REGULATION	3-0-0-1-10	Energy and Economic Development: National and International Perspective, Structure of Energy Demand and Supply,, Energy Value Chain and Energy Accounting, India Energy Scenario 2047, Economics of Energy and Exhaustible Resources , Energy Security, Energy Policy and Planning, Modelling for Energy Markets: Applications in General Algaebric Modelling System (GAMS), International Markets for Energy: Oil, Coal, Natural Gas and Uranium, Indian Energy Markets: Oil & Gas, Coal and Electricity, Private Investment in Energy Sectors: NELP, Coal Policy, Power Policy, Regulation of Indian Energy Sectors Electricity, Oil & Gas and Coal Sectors, Pricing in Energy Markets: Electricity, Coal, Oil and Natural Gas, Functioning of Power Exchange and Commodity Exchanges (Energy), Cross Border Energy Cooperation, Energy and Environment, Climate Change, UNFCC, Kyoto Protocol and beyond, Clean Development Mechanism and its Process, International Carbon Markets and Carbon Finance, National Action Plan on Climate Change, JNN National Solar Mission, Renewable Energy: Technology, Economics and Policy, Market for Renewable Energy Certificates, Energy Conservation, Market for Energy Efficiency: ESCO and Market for Ecerts (White Certificates). One project work on relevant topic. **Course Reference**: 1. Environmental and Natural Resource Economics, Tom Tietenberg, AddisonWesley, 2000; 2. International Energy Markets: Understanding Pricing, Policies, and Profits, Carol Dahl, Penn Well Books, ISBN: 9780878147991, 2004; 3. Energy Efficiency: Principles and Practices, Penni McLeanConner, ISBN: 9781593701789, 2009; 4. Economics of Regulation and Antitrust Viscusi, Vernon & Harrington, MIT Press, 2000; 5. Integrated Energy Policy, Report of the Expert Committee, Govt. of India, Planning Commission, New Delhi, August 2006; 6. Relevant Publications

			of World Energy Council and International Energy Agency, World Bank and Asian Development Bank; 7. Relevant reports of respective Ministries; 8. Other relevant journal articles, reports, policy documents, regulations of regulatory commissions, case studies and class notes.
MBA683A	POWER SECTOR REFORM & REGULATION: THEORY AND PRACTICE	3-0-0-0-9	Electricity value chain and economic development. Structure of Electricity Demand and Supply: Power Sector Scenario in India. Theories of Regulation and Economics of Regulation. Power Sector Reform and Regulation: International and Indian Experience. Electricity Act 2003 and related policies including National Electricity Policy, National Tariff Policy, Rural Electrification Policy.Regulatory Process: Functions of Electricity Regulatory Commissions and APTEL. Rate of Return Regulation and Performance Based Regulation. Determining Aggregate Revenue Requirement and Tariffs for Regulated Entities. Availability Based Tariff and Multiyear Tariff. Principles of Retail Tariff Design Single Part, Multipart, TOD Tariffs etc. Unbundling, Privatization and Franchisee Development. Power Purchase Agreement. Competitive Bidding Guidelines & Ultra Mega Power Projects. Competition in Power Sector: Open Access and Retail Competition. Functioning of Power Exchanges and Market Monitoring. Distribution Reforms and Performance incl. RAPDRP and RGGVY. Regulatory Approach to Promote Renewable Energy: Renewable Portfolio Obligation, Feedin Tariff and Renewable Energy Certificates.Demand Side Management. Consumer issues in electricity sector. **Course Reference**: 1. Electricity Markets, Harris, Chris, John Wiley, 2006; 2. Electricity Economics: Electricity Economics: Regulation and Deregulation, Geoffrey Rothwell, Toms Gmez, Wiley IEEE Press, 2003; 3. Economics of Regulation and Antitrust Viscusi, Vernon & Harrington, MIT Press, 2000; 4. Economics of Regulation Alfred Kahn. MIT Press, 1998; 5. India Infrastructure Reports 3i Network, OUP; 6. Power System Economics: Designing Markets for Electricity, Steven Stoft, Wiley IEEE Press, 2001; 7. Privatisation, Restructuring and Regulation of Network Utilities David M. Newbery, MIT Press, 2001; 8. Other relevant books, journal articles, reports, laws, policy documents, regulations and tariff orders of regulatory commissions, forum of regulators, case studies and class notes.
MBA697	SUMMER PROJECT	0-0-0--0	During the summer after first two semesters, each student will take up a summer project in an industrial or service organization for 810 weeks. During this period, the student will work under the guidance of an executive of the host organization, complete the assignment, prepare a written report, and make a presentation during the third semester.
MBA697A	SUMMER PROJECT	0-0-0-0-0	During the summer after first two semesters, each student will take up a summer project in an industrial or service organization for 810 weeks. During this period, the student will work under the guidance of an executive of the host organization, complete the assignment, prepare a written report, and make a presentationnduring the third semester.
MBA698	MANAGEMENT SEMINARS	----0	Management Seminars

MBA698A	MANAGEMENT SEMINARS	0-0-0--0	Management Seminars
MBA699	PROJECT I	----4	In this course, each student will take up a management project or management topic under the guidance of a specific faculty. Towards the end of the semester, the student will present a final report of the project.
MBA699.	PROJECT I	----4	In this course, each student will take up a management project or management topic under the guidance of a specific faculty. Towards the end of the semester, the student will present a final report of the project.
MBA699A	CAPSTONE PROJECT	0-0-0-0-9	In this course, each student will take up a management project or management topic under the guidance of a specific faculty. Towards the end of the semester, the student will present a final report of the project.
MBA711A	CHANGE MANAGEMENT AND ORGANIZATIONAL DEVELOPMENT	3-0-0-0-5	Understanding Organizational Change: Definition and Types, Systems Perspective, Identification and Assessment of Factors Leading to Change, Change Management Process: An Overview, Resistance to the Process of Change, Reasons and Mitigating Measures, Lewin's Process, Constructive Destruction, Role of IT in Change Management, Business Process Reengineering, Appreciative Inquiry, Change Management through OD Intervention. **Course Reference**: 1. Grieves, J. (2010). Organizational Change: Themes and Issues. Oxford; 2. Brown, D, & Harvey, D. (2206). An Experential Approach to Organizational Development. Pearson; 3. Cummings, C.G. & Worley, C.G. (2005). Organizational Development and Change. Thomson; 4. Additional readings: relevant cases and articles. 29-MAR-2016
MBA712A	ORGANIZATIONAL STAFFING	3-0-0-0-5	Introduction to Organizational Staffing: Steps and Strategic Linkages; Manpower Planning; Job Analysis Techniques; Competency Based Staffing; Models and Mapping Techniques; External and Internal Recruitment Process; External and Internal Selection Process; Concept of Measurement, Reliability and Validity; Selection Methods and Tools: Utility, Relevance and Applicability; Organizational Socialization and Deployment; Succession Planning and Career Progression; Use of IT in Staffing; Other Emerging Issues. **Course Reference**: 1. Herbert G. Heneman & T.A. Judge, Staffing Organizations. McGraw Hill; 2. Phillips, J. M. Strategic Staffing. Prentice Hall; 3. Additional readings: relevant cases and articles. 29-MAR-2016
MBA713A	PERFORMANCE MANAGEMENT	3-0-0-0-5	Objectives of Performance Mangement, Historical Account, Performance Planning: Synchronization with Organization's vision, mission, strategy and goals, Issues and Problems, Defining and Measureing Performance, Methods of Performance Appraisal, Communication of Feedback, 360 degree Performance Feedback, Rewards and Recognition, Career Management, Role of Performance Management in fostering Employee Engagement, Re designing Jobs for better Performance, Key Implications of Performance Management, Legal and Ethical Perspectives. **Course Reference**: 1. Aguinis, H. Performance Management (3rd ed.). McGraw Hill; 2. Cardy, R.L. & Leonard, B.

			Performance Management: Concepts, Skills and Exercises (2nd ed.). M. E. Sharpe; 3. Rao, T.V. Performance Management and Appraisal Systems: HR Tools for Global Competitiveness. Sage; 4. Additional readings: relevant cases and articles. 29-MAR-2016.
MBA781A	PUBLIC PRIVATE PARTNERSHIP (PPP) IN INFRASTRUCTURE	3-0-0-0-5	Infrastructure, Economic Development and need for PPP. Definition and scope of infrastructure. Economics of infrastructure Natural Monopoly. Modes of PPP. Policy Framework for Infrastructure Investment in India VGF and its alternatives. Structuring a PPP Project Proposal RPQ & RFP. Selected Case Studies from Power, Roads, WTE, Railways, Metro, Ports, Airports etc. Policy Framework for PPP Across Major Sectors. Global Best Practices for PPP Projects. Dealing with Unsolicited Bids. The, Swiss Challlange. Projects Caselets A Case Analysis of a PPP Project (on mutually agreed topic). **Course Reference**: 1. E.R. Yescommbe, Public Private Partnerships Priciples of Policy and Finance, Elsevier Finance (2007); 2. A Guide book on Public Private Partnership in Infrastructure, UNESCAP, Bangkok, 2011; 3. A World Bank Resource for PPPs in Ifrasctructure, ppp.worldbank.org; 5. PPP Toolkit, http://toolkit.pppinindia.com; 6. Database of Infrastrcture Projects in India, https://infrastructureindia.gov.in/; 7. India Infrastructure Reports 3iNetwork, OUP; 8. Other relevant books, journal articles, reports, laws, policy documents, regulations and tariff orders of regulatory commissions, forum of regulators, case studeis and class notes. 05-APR-2016
MBA782A	RENEWABLE ENERGY - ECONOMICS, POLICY AND REGULATION	3-0-0-0-5	Drivers for Renewable Energy. RES Wind, Solar, Biomass, SHP, Ocean, WTE etc. RE Development National and International Perspective. Economics of Renewable Energy. Policy and Regulatory Instruments to Promote RE. Electricity Act 2003 and other relevant legislations policies. Renewable Portfolio Obligationa and Feed in Tariff. Market for Renewable Energy Certificates (RECs). NAPCC and Jawaharlal Nehru National Solar Mission. Competitive Bidding for Renewable Energy. Developing and Implementing a Solar Rooftop Program. Challenges for VRE integration Forecasting and Solutions. Climate Change and Green Energy Finance: Business Models. Projects Caselets on mutually agreed topics. **Course Reference**: 1. Miguel Mendonca, Feed in Tariff, Earthscan, 2007; 2. Evaluating Policies in Support of the Development of Renewable Power; 3. REN21. Renewables 2015, Global Status Report; 4. Re Policy Database; 5. Indian Renewable and Energy Efficiency and Policy Database; 6. Other relevant books, journal articles, reports, laws, policy documents, regulations and tariff orders of regulatory commissions, forum of regulators, case studies and class notes. 05-APR-2016

DESIGN PROGRAMME(MDES)

DESIGN PROGRAMME

BT/BS-M.Des. (Category – C) *(from other departments)*						Template No. DES-1
	UG Pre-Requisites	PG Requirements				
	1st to 6th	7th and 8th	SUMMER	9th	10th	
COURSES	UG OE-1* [05/12]	DES601A [09]	M.Tech. Thesis [18]	M.Tech. Thesis [27]	M.Tech. Thesis [27]	
	-	DES602A [09]	-	-	-	
		DES603A [09]				
		DES682A [09]				
		DES681A [09]				
		DE PG-1 [09]*				
	05/12	54	18	27	27	

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

UG Component : 05 Credits
PG Component : 54 Credits
Thesis Component : 72 Credits

Basket – A	Basket – B
ART105A [11]	DES626A [09]
ART102A [11]	DES630A [09]
ME251A [05]	DES633A [09]
CS220A [12]	
EE200A [11]	

REMARKS:

1) *UG OE should be selected from Basket – A.
2) OE PG should be selected from Basket – B.
3) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Des. part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
4) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the dual degree programme. These will be waived from the parent department's BT/BS programme requirements and counted towards PG requirements.

DEPARTMENT OF MDES			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
DES601	DESIGN THEORY		Design Philosophy, Art (aesthetics) in ID, History of Design, Human Experiencein Design, Design Elements, Design Principles, Theory of Colour, Colour Aesthetics, Subject of Colour, Design Paradigm, Art Design & Society, Indian Tradition andProducts.Studio: Form, Space and Texture; 2D and 3D Form Analysis, Colour and Texturein 2D and 3D surface; Colour Aesthetics; Product Analysis and Ergonomics, Product Design and Developments.
DES601A	DESIGN THEORY		Design Philosophy, Art (aesthetics) in ID, History of Design, Human Experiencein Design, Design Elements, Design Principles, Theory of Colour, Colour Aesthetics, Subject of Colour, Design Paradigm, Art Design & Society, Indian Tradition andProducts.Studio: Form, Space and Texture; 2D and 3D Form Analysis, Colour and Texturein 2D and 3D surface; Colour Aesthetics; Product Analysis and Ergonomics, Product Design and Developments.
DES602	DESIGN PRACTICE I	2-0-2-0-4	Stages of a Product and Concurrent Engineering; Problem Formulation, Specifications and Constraints; Creating Forms; Configuration Optimisation; Coupled, Decoupled and Uncoupled designs; Product of Static and Dynamic Societies; Material Experimentation; Construction Technique; Model Building; Decision Making, Addressing Failures and Courage to Create; Interpersonal Skills; Robust Design,Incubation;

			Economic Considerations; Micro and Macro Designs; Introduction toElectronics; Laboratory on Problem Formulation, Innovation, Decision Making,Interpersonal Skills, etc., through Group Discussion, Case studies, Books and Journals Review.
DES602A	DESIGN PRACTICE I	2-0-3-0-9	Stages of a Product and Concurrent Engineering; Problem Formulation, Specifications and Constraints; Creating Forms; Configuration Optimisation; Coupled, Decoupled and Uncoupled designs; Product of Static and Dynamic Societies; Material Experimentation; Construction Technique; Model Building; Decision Making, Addressing Failures and Courage to Create; Interpersonal Skills; Robust Design, Incubation; Economic Considerations; Micro and Macro Designs; Introduction to Electronics; Laboratory on Problem Formulation, Innovation, Decision Making, Interpersonal Skills, etc., through Group Discussion, Case studies, Books and Journals Review.
DES603	DESIGN PRACTICE II	2-0-3-0-4	Construction of Forms, Geometrical Transformations; Surface Modeling; Representation of 3D Shapes; Solid Modeling; Simulation in CAED, Rapid Prototyping & Tooling; Strength and Stiffness of Structural Elements and Mechanisms; Introduction to Control; Electronics Signal Processing; Sensors and Actuators; Micro Electro Mechanical Systems; Mechatronics; Design of Embedded Systems; Intelligent Product Design. Laboratory: 2D3D Modeling, Operation of Rapid Tooling and Prototyping Instruments, Development of Simple Sensors and Actuators, Design of Products with Embedded Sensors etc.
DES621	CREATIVE VISUALIZATION	2-0-3-0-4	Theory: Art movements and design: Principles of style in art, product design, architecture and graphic design: Photography, Design and performing art: Art and perception; Methodology of criticism and appreciation. Studio Short workshops, projects, and field trips in the above, mentioned areas (photography, film making, lights, stage craft, script writing, editing, product development) to emphasize visualization powers in an attempt to build a personal vision.
DES621A	CREATIVE VISUALIZATION	2-0-3-0-9	Theory: Art movements and design: Principles of style in art, product design, architecture and graphic design: Photography, Design and performing art: Art and perception: Methodology of criticism and appreciation Studio: Short workshops, projects, and field trips in the above, mentioned areas (photography, film making, lights, stage craft, script writing, editing, product development) to emphasize visualization powers in an attempt to build a personalvision.
DES623	TOPICS IN MOTION PICTURES	2-0-3-0-4	Topics in motion pictures require a combined practical and theoretical approach for realizing the creative media in its totality. The proposed course would offer students the opportunity to acquire a range of transferable and practical skillsin film and television productions.Concise and brief history of motion pictures; Analysis and a general approach to the criticism of film and television media; Approach and methods in these forms of media productions; Overview of the digital media arts field with anemphasis on technological

			developments and their integration in art researchand production.Students would be introduced to contemporary and historical directions, keyconcepts and methodologies through seminar lectures, research presentations, practical exercises and a final project. Classes would be supplemented with viewing a range of productions, individual and group critiques, presentations, demonstrations and practical exercises to explore traditional and modern methods and explore both technical and creative approaches to the medium. The, course will also include short workshops supported by specialized professionalsin the related fields.
DES623A	TOPICS IN MOTION PICTURES	2-0-3-0-9	Topics in motion pictures require a combined practical and theoretical approach for realizing the creative media in its totality. The proposed course would offer students the opportunity to acquire a range of transferable and practical skillsin film and television productions. Concise, and brief history of motion pictures; Analysis and a general approach to the criticism of film and television media; Approach and methods in these forms of media productions; Overview of the digital media arts field with an emphasis on technological developments and their integration in art research and production. Students would be introduced to contemporary and historical directions, key concepts and methodologies through seminar lectures, research presentations, practical exercises and a final project. Classes would be supplemented with viewing a range of productions, individual and group critiques, presentations, demonstrations and practical exercises to explore traditional and modern methods and explore both technical and creative approaches to the medium. The, course will also include short workshops supported by specialized professionals in the related fields.
DES624	ELEMENTS AND PRINCIPAL OF DESIGN	2-0-2-4-4	The course intends to develop the following areas(i) Elements of Design value, color, form, shape, line and texture. Each elenment is to be examined theoretically along with studio exercises and evaluated through consumer products (2D & 3D). (ii) Principal of Design would evaluate contrast, rhythm, unity, emphasis, pattern, movement, and balance on the basis of Design Elements. The course proposes to develop through understanding of the elements and principles of design and their corelationship. The, course intends in developing understanding on the above issues and executes projects to examine elements and principles of design. Studentsare expected to develop knowledge and practical skill through theoretical and practical training. Students are required to develop products, give seminars and submit research paper on chosen topics.
DES625	FORM AND STYLE	2-0-2--4	Theory: Form envelops and assists function in the process, creates a network of values that is termed as Style. Studies in form and style concerns the conceptualization, exploration, and development of form and style in both product design and Visual commnication. The course will explore various bases for creative visualization like Fantasy. Metaphors, Cultural connotations and Bionics in the context of form making.From analysis Analysis of principles of form in

			relation with society study of evolution of forms in products 2D and 3D space analysis Dominant sub dominant subordinate relationship, Recall of forms Tensile design Motion andform, Light space analysisFor Visual communication form will ne explored in the context of concept communication and the application of information theory to visual structures.This will include case studies of advertisement campaigns like Amul Silk cuntetc.The course evaluates patterns of aesthetic, ergonomic and market behaviour towards forms.Studio: Form development assignments in both Product and visual communications will deal with the evolution of form in relation with exploration and function.Each assignment will complete the design process and its various stages from conceptualization, comparative studies, and usability issues to market trendsas related to the study of Form. The study of the design process will help inunderstanding the shifts between analytical and creative phases in differentstages of design that is conceptualizattion and manufacturability gaps. Various, visual structures and alternative display formats wiill be explored throughthe assignments. The course, is envisaged in collaboration with assignments from the industry wherever possible in which the primary work will take place in the Lab andthe critical evaluatiion in the industry. The course requires extensive field studyfor usability and market trends.
DES625A	FORM AND STYLE	2-0-3-0-9	Theory: Form envelops and assists function in the process creates a network of values that is termed as Style. Studies in form and style concerns the conceptualization, exploration, and development of form and style in both product design and Visual commnication. The course will explore various bases for creative visualization like Fantasy. Metaphors, Cultural connotations andBionics in the context of form making.From analysis Analysis of principles of form in relation with society study of evolution of forms in products 2D and 3D space analysis Dominant sub dominant subordinate relationship, Recall of forms Tensile design Motion andform, Light space analysis For Visual communication form will ne explored in the context of concept communication and the application of information theory to visual structures.This will include case studies of advertisement campaigns like Amul Silk cuntetc.The course evaluates patterns of aesthetic, ergonomic and market behaviour towards forms.Studio: Form development assignments in both Product and visual communications will deal with the evolution of form in relation with exploration and function.Each assignment will complete the design process and its various stages from conceptualization, comparative studies, and usability issues to market trendsas related to the study of Form. The study of the design process will help in understanding the shifts between analytical and creative phases in different stages of design that is conceptualizattion and manufacturability gaps. Various, visual structures and alternative display formats wiill be explored throughthe assignments. The course is envisaged in collaboration with

			assignments from the industry wherever possible in which the primary work will take place in the Lab andthe critical evaluatiion in the industry. The course requires extensive field studyfor usability and market trends.
DES626	INTERACTION DESIGN	2-0-2--4	Interaction Design defines behavioral pattern and builds the performance level of technical, environmental, biological and organizational systems i.e. software, products, mobile devices, environments, services, wearable, and even organizations themselves to name a few. The behavior or the interaction of a manufacture d article or a scheme in response to its user group is the primary concern of this topic in design. Students are expected to collect information through user research following the various user research methodologies, generate interactive scenarios and strategies, design stressing upon behaviour as well as form, and consider the evaluation process of design in terms of usability and emotional factors and propose solutions for the ease of use in physical or virtual productsor a system. Interactive objects, spaces and services are concieved taking into consideration the different design concerns as well as by exploiting Information and Communication Technogy (ICT) potentialities as term projects.
DES627	MANAGEMENT OF DESIGN AND INNOVATION	2-0-2--4	Identification of Opportunities and the creative mind, Problem Based ideation, Creative Problem solving, Market Innovation and Brands, Strategy and Organization for the Creative Business, Networks and Collaboration for Design Innovation and cultural Industries, Competitive Design performance Management for the Design Business over the Life Cycle.
DES628	DESIGN, CULTURE AND SOCIETY	2-0-2--4	Understanding the Dynamics of Indian Society : Social Units and Institutions,Cultural Adaptations, Exploring Culture : Attributes, Cultural Practices, Cultural Growth and Cultural Integration , Methods of cultural Inquiry : Comparative Methods, Fieldwork, Ethnographic Study, and Perspective on Design trends, Indigenous Design Culture : Proletarian Design Innovations, Role of Design within Societal Structure and Cultural Framework and Understanding Users, User Experience Design : UE Research Tecniques, Trend Mapping : Research Methodology assessing, scoping, digging and refining the data, information, knowledge andinsight layers; Cultural triangulation how observation, interrogation and intuition add the key and core vital layer to understanding the data assessed, the knowledge acquired and the insights delivered; Quantitative sampling; Visualand trend mapping techniques turning insights into market strategies; Using forecasting to develop products and new brand directions.
DES629	INTRODUCTION TO CRITICAL ART APPRECIATION	2-0-2-0-4	Contemporary Art Theory & Practice, Art and its implications Society & Culture, Role of Art and Artist in Socio Cultural Framework, Understanding Visual CultureHistorical and Global Perspective, Methodology for Critical Thinking in the context of Art Appreciation, Principles and Norms of Art, Communication in VisualArts, Relative studies in diverse cultural expressions.

DES681	DESIGN PROJECT I	0-0-6--4	Introduction to Graphics, Introduction to Graphics Software, Introduction to Style, Introduction to Multimedia Application, Introduction to CAD Application, User Consumer Interaction Study, Media Communication, Ergonomics, Material Exploration.
DES681A	DESIGN PROJECT I	1-0-6-0-9	Introduction to Graphics, Introduction to Graphics Software, Introduction to Style, Introduction to Multimedia Application, Introduction to CAD Application, User Consumer Interaction Study, Media Communication, Ergonomics, Material Exploration.
DES682	DESIGN PROJECT II	2-0-6-0-4	Manufacturability Studies, Embedded products, Product styling, Package Designing, Information design, HCI, GUI, Animation, Film appreciation, Print Making.
DES682A	DESIGN PROJECT II	1-0-6-0-9	Manufacturability Studies, Embedded products, Product styling, Package Designing, Information design, HCI, GUI, Animation, Film appreciation, Print Making.
DES689	TOPICS IN DESIGN	2-0-3-0-4	Lectures and Workshops on Various Topics in Design like Ergonomics, Graphic Design and Typography, Design Management, Visual Image Design, Composition and Media Art, Aesthetics and Forms, Role of Design in ICT, Auto Design, Product Simulation, Packaging Design, Sustainable Design through Practical Exercises, Studio Projects, Field Trips.
DES698	SPECIAL STUDIES/PROJECT COURSES IN DESIGN	0-0-0--4	Cognitive Design; Design Management; Human factors in Ergonomics Design; Usability & Usercentric Design; Axiomatic Design; Human Computer Interface Design (HCI), etc.
DES698A	SPECIAL STUDIES/PROJECT COURSES IN DESIGN	0-0-0-0-9	Cognitive Design; Design Management; Human factors in Ergonomics Design; Usability & Usercentric Design; Axiomatic Design; Human Computer Interface Design (HCI), etc.
DES699	M DES THESIS	0-0-0--	M. Des. Thesis
DES699B	M DES THESIS	0-0-0--4	M DES THESIS
DES799	PH.D THESIS	-0-0-0-	Ph. D. Thesis

MECHANICAL ENGINEERING

MECHANICAL ENGINEERING

B.TECH.								Template No. ME-1
	SEMESTER							
	1st	2nd	3rd	4th	5th	6th	7th	8th
C	MTH101A [11]	MTH102A [11]	ESC201A [14]	HSS-2 (Level-1) [11]	HSS-3 (Level-2) [09]	HSS-4 (Level-2) [09]	HSS-5 (Level-2) [09]/ DE-2 [09]	DE-2 [09]/ HSS-5 (Level-2) [09]
O	PHY102A [11]/ PHY103A [11]	PHY103A [11]/ PHY102A [11]	ESO/SO-1 ESO201A [11]	ESO/SO-5 ESO202A [11]	ME301A [06]	ME341A [10]	ME401A [10]	ME461A [09]
U	PHY101A [03]/ CHM101A [03]	CHM101A [03]/ PHY101A [03]	ESO/SO-2 ESO209A [08]	ESO/SO-6 ESO203A [13]	ME321 [07]	ME351A [08]	ME451A [09] (UGP-2)	ME452 [06] (UGP-3)
R	TA101A [09]	ESC101A [14]	ME251A [05]	ME222A [07]	ME352A [07]	ME354A [10]	OE-3 [09]	OE-4 [09]/ DE-3 [09]
S	LIF101A [06]	CHM102A [08]	TA202A [06]/ TA201A [06]	ME231 [10]	ME361A [10]	OE-2 [09]	OE-4 [09]/ DE-3 [09]	OE-5 [09]
E	ENG112A/HSS-1 (Level-1) [11]	PE102A [03]	ESO/SO-3 MSO202a [06]	COM200A [05]	ME399A [02]	DE-1 [09]	UGP-4 [09] (ME498A) (Extra Credits)	OE-6 [09]
S	PE101A [03]		ESO/SO-4 MSO203b [06]	TA201A [06]/ TA202A [06]	OE-1 [09]	UGP-1 [04] (ME398A) (Extra Credits)		
	54	50	56	63	50	55/59	55/64	51

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	101	Credits
UGP-2 and UGP-3	:	15	Credits
Department Elective (DE)	:	27	Credits
Open Elective (OE)	:	54	Credits
ESO/ SO	:	55	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	**425**	**Credits**

REMARKS:

1) UGP-2 (ME451A) and UGP-3 (ME452A) are departmental compulosry courses for BTech students. However, these are optional for BT-MT students who apply for conversion to BT-MT program before the end of the sixth semester. Such students may do any two DE PG courses as substitute for UGP-2 and UGP-3. If a student opts to take ME451A or ME452A after applying for the dual degree programme before the end of the 6th semester, these courses WILL NOT count towards his/her DE-PG requirement .
2) Students registering for ME451A (UGP-2) must form BTP groups and inform Convener, DUGC, by April 30th of 6th Semester.
3) ME students applying for BT-MT in ME after the formation of BTP groups will have to take UGP-2 and UGP-3. Neither of these courses may be dropped. Out of UGP-2 and UGP-3, only UGP-3 may be counted towards DE-PG credits for these students.
4) UGP-1 & UGP-4 are optional and do not count towards graduation requirements.
5) 15 credits of UGP-2&3 and 18 OE credits may be waived from the minimum BT requirements for students opting for dual degree in ME itself.
6) Upto 36 OE credits may be waived from the minimum requirements for students opting for Dual Degree in any other department or the Double Major programme.

BT-MT (PG Part – Category A) (*from the same department*)				Template No. ME-2
C				
O	7th	8th	9th	10th
U	DE PG-1 [09]	DE PG-4 [09]	M.TECH. THESIS [36]	M.TECH. THESIS [36]
R	DE PG-2 [09]	DE PG-5 [09]	-	-
S E	DE PG-3 [09]/ OE PG-1 [09]	DE PG-6 [09]/ OE PG-1 [09]		
S	27	27	36	36

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Component	:	54	Credits
Thesis Component	:	72	Credits

REMARKS:

1) UGP-2 and UGP-3 are compulsory for UG ME students, but not for BT-MT ME students. BT-MT ME students have to take 18 credits of DE PG instead of 15 credits of UGP-2 and UGP-3. However, ME students applying for BT-MT in ME after the start of 7th semester will have to take UGP-2 and UGP-3. Neither of these courses may be dropped. Out of UGP-2 and UGP-3, only UGP-3 may be counted towards DE-PG credits. In that case, students will have to make up the remaining 12 credits of DE PG with additional PG level ME courses.
2) All courses to be taken with the permission of Supervisor/ DUGC Convener.
3) AE675A may count as DE PG in lieu of ME623A. Similar equivalences can be established by the DUGC after deliberating the course content on a case to case basis.
4) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech. part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
5) Upto 18 OE credits may be used from the BT minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the BT programme and counted towards PG requirements.

BT-MT (PG Part – Category – B) *(from other departments)*				Template No. ME-3
Sl. No.	Specialization	Compulsory Course Credits	Elective Credits	Thesis Credits
1.	SOLID MECHANICS AND DESIGN (SMD)	ME621A [09] ME625A [09] ME681A [09]	DE PG-1 [09] DE PG-2 [09] DE PG-3 [09]	M.TECH. THESIS [72]
2.	FLUID & THERMAL SCIENCES (FTS)	ME631A [09] ME641A [09] ME642A [09] ME681A [09]	DE PG-1 [09] DE PG-2 [09]	M.TECH. THESIS [72]
3.	MANUFACTURING SCIENCES (MFS)	ME661A [09] ME662A [09] ME663A [09] ME681A [09]	DE PG-1 [09] DE PG-2 [09]	M.TECH. THESIS [72]

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Component : 54 (27 Compulsory + 27 Electives) Credits for SMD
PG Component : 54 (36 Compulsory + 18 Electives) Credits for FTS and MFS
Thesis Component : 72 Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ DUGC Convener.
2) Some of the compulsory courses in any of the above streams may be replaced with DE PG by the DUGC Convener based on the UG courses done by the student for his UG graduation requirement.
3) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech. part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
4) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the BT/BS-MT dual degree programme. These will be waived from the parent department's BT programme requirements and counted towards PG requirements.

DOUBLE MAJOR		Template No. ME-4
C	Odd Semester	Even Semester
	Pre-Requisites	
O	ESO201A [11]/ ESO202A [11]	ESO201A [11]/ ESO202A [11]
	ESO209A [08]	
U	19	11
	ME Mandatory Courses	
R	ME251A [05]	ME231A [10] *
	ME301A [06]	ME341A [10] **
S	ME321A [07]	ME351A [08]
	ME352A [07]	ME354A [10]
E	ME361A [10]	ME461A [09]
	ME401A [10]	
S	45	47

TOTAL MANDATORY CREDITS FOR SECOND MAJOR IN MECHANICAL ENGINEERING: 92 CREDITS

REMARKS:

1) *Equivalent courses for ME231A are (ESO204A + AE311A) or (ESO204A + CE262A).
2) **Equivalent course for ME341A is CHE312A.
3) Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.

MINOR		Template No. ME-5
Title	MANURACTURING SCIENCES	COMPUTATIONAL TECHNIQUES IN MECHANICAL ENGINEERING
	Any THREE from:	Any THREE from:
C		
O	ME661A [09] (Prerequisite TA202A)	ME623A [09] (Prerequisite ESO202A, MSO203B)
U	ME662A [09] (Prerequisite TA202A)	ME630A [09] (Prerequisite ESO201A, ESO204A, MSO203B)
R	ME663A [09] (Prerequisite ESO202A, MSO203B)	ME685A [09] (Prerequisite – No backlog in core courses)
S E	ME664A [09] (Prerequisite TA202A, ESO204A or Equivalent Heat Transfer Course)	ME751A [09] (Prerequisite TA101A)
S	ME665A [09] (Prerequisite TA202A)	MEXXXA [09] (Nonlinear Finite Element Techniques in Solid Mechanics)
	ME774A [09] (Prerequisite ESO202A, MSO203B)	MEXXXA [09] (Atomistic Simulations in Engineering)
	ME751A [09] (Prerequisite TA101A)	
	ME761A [09] (Prerequisite TA202A)	
	27	27

DEPARTMENT OF ME			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
ME222A	NATURE AND PROPERTIES OF MATERIALS	2-0-1-0-7	History of engineering materials, Engineering materials, Materials property chart, Crystal structure, Imperfections of solids, Mechanism of strengthening in metals, Hall Petch effect, Xray diffraction, Fracture: Ductile, brittle, fatigue. Griffith criterion, SN curve, Creep, Phase diagram(binary), Ironcarbon system, Heat treatment of metals, Electrical properties, Thermal properties, Magnetic properties, Optical properties, Corrosion, Oxidation, Thermal stability ,Wear, abrasion, friction of materials, Characterization techniques: Optical microscopy, scanning electron microscopy, transmission electron microscopy, atomic force microscopy, Polymer andits characterization, Viscoelasticity, Nanomaterials and its important properties at nanoscale, Composites: Characterization of composites, Ionic polymer matrix composites, Shape memory alloy, Intelligent Multifunctional materials, Economics, Environment, and Sustainability
ME231	FLUID MECHANICS	3-0-0-1-4	Reynolds Transport Theorem; Integral form of continuty, momentum and energy; Eulerian and lagrangian viewpoints; Constitutive relations; Navier Stokes equations: Exact solutions; Potential flow; Boundary layer theory; Separation and drag; Turbulent flow: Reynolds averaged equations; Turbulent flows in pipesand channels; compressible flows.
ME231A	FLUID MECHANICS	3-0-1-0-10	Reynolds Transport Theorem; Integral form of continuty, momentum and energy; Eulerian and lagrangian viewpoints; Constitutive relations; Navier Stokes equations: Exact solutions; Potential flow; Boundary layer theory; Separation and drag; Turbulent flow: Reynolds averaged equations; Turbulent flows in pipesand channels; compressible flows.
ME251	ENGINEERING DESIGN AND GRAPHICS	2-0-3-0-4	Theory of general engineering design, conceptual design, embodiment design, designing to standard, basic sketching, machine drawing, dimensioning as perstandards, fits and tolerances, machine elements, assembly drawing, geometrical modeling, and use of CAD software for modeling and animation. **Course Reference**: 1. Machine Drawing by Ajeet Singh, Me Graw Hill2. Machine Drawing by N.D. Bhatt and V.M. Panchal, Charotar Publications.
ME251A	ENGINEERING DESIGN AND GRAPHICS	1-0-2-0-5	Theory of general engineering design, conceptual design, embodimentdesign, designing to standard, basic sketching, machine drawing, dimensioning as perstandards, fits and tolerances, machine elements, assembly drawing, geometrical modeling, and use of CAD software for modeling and animation. **Course Reference**: 1. Machine Drawing by Ajeet Singh, Me Graw Hill2. Machine Drawing by N.D. Bhatt and V.M. Panchal, Charotar Publications.
ME300	SUMMER	-0-0--0	Six weeks training after the sixth semester in the Industry.

	INDUSTRIAL TRAINING		
ME301	ENERGY SYSTEMS I	3-0-0-0-4	Introduction to energy resources and conversion systems: Fossil fuels, Nuclear energy, Hydrogen, Renewable energy sources. Thermal energy to Mechanical Energy Conversion: Internal Combustion Engine Technology, Real Cycles, Combustion, Emissions, Performance and Testing. Mechanical Energy to Thermal Energy Conversion: Modern Refrigeration and Airconditioning Systems Energy Conversion Systems. **Course Reference**: 1. Sorensen, H, McGrawHill, USA Principles of Energy Conversion, Cup! A.W., TMH Internal Combustion Engine Fundamental, I B Heywood, McGrawHill, USA; 2. A course in internal combustion engines, by: Mathur and Sharma, Dhanpat Rai & Sons; 3. Internal Combustion Engine, Pundir B P, Narosa. Refrigeration and Air Conditioning, Arora C P, TMH Principles of Refrigeration, Dossat R, PHI
ME301A	ENERGY SYSTEMS I	2-0-0-0-6	Introduction to energy resources and conversion systems: Fossil fuels, Nuclear energy, Hydrogen, Renewable energy sources. Thermal energy to Mechanical Energy Conversion: Internal Combustion Engine Technology, Real Cycles, Combustion, Emissions, Performance and Testing. Mechanical Energy to Thermal Energy Conversion: Modern Refrigeration and Airconditioning Systems Energy Conversion Systems. **Course Reference**: 1. Sorensen, H, McGrawHill, USA Principles of Energy Conversion, Cup! A.W., TMH Internal Combustion Engine Fundamental, I B Heywood, McGrawHill, USA; 2. A course in internal combustion engines, by: Mathur and Sharma, Dhanpat Rai &Sons; 3. Internal Combustion Engine, Pundir B P, Narosa. Refrigeration and Air Conditioning, Arora C P, TMH Principles of Refrigeration, Dossat R, PHI
ME321	ADVANCED MECHANICS OF SOLIDS	3-0-0-0-4	Introduction to Cartesian tensors; Strains: Concept of strain, derivation ofsmall strain tensor and compatibility; Stress: Derivation of Cauchy relations and, equilibrium and symmetry equations, principal stresses and directions; Constitutive equations: Generalized Hooke’s law including thermoelasticity, Material symmetry; Boundary Value Problems: Definition of the bvp in linear elasticity including concepts ofuniqueness and superposition; 2D plane stress and plane strain problems, introduction togoverning equations in cylindrical and spherical coordinates, axisymmetric problems(examples may include problems on curved beams, thermoelasticity, torsion of noncircular cross sections, contact problems in 2D, problems on wedges and crack tip fields);3D problems by potential methods; Energy methods and problems. **Course Reference**: 1. Timoshenko and Goodier, Theory of Elasticity, McGraw Hill Publishing Company, 1970; 2. Bower, Applied Mechanics of Solids, CRC Press, 2009.Saad, Elasticity: Theory Application and Numerics, Academic Press, 2004.
ME321A	ADVANCE MECHANICS OF	2-0-1-0-7	Introduction to Cartesian tensors; Strains: Concept of strain, derivation ofsmall strain tensor and compatibility; Stress:

	SOLIDS		Derivation of Cauchy relations and,equilibrium and symmetry equations, principal stresses and directions; Constitutive equations: Generalized Hooke's law including thermoelasticity, Material symmetry; Boundary Value Problems: Definition of the bvp in linear elasticity including concepts of uniqueness and superposition; 2D plane stress and plane strain problems, introduction togoverning equations in cylindrical and spherical coordinates, axisymmetric problems(examples may include problems on curved beams, thermoelasticity, torsion of noncircularcross sections, contact problems in 2D, problems on wedges and crack tip fields);3D problems by potential methods; Energy methods and problems. **Course Reference**: 1. Timoshenko and Goodier, Theory of Elasticity, McGraw Hill Publishing Company, 1970; 2. Bower, Applied Mechanics of Solids, CRC Press, 2009.Saad, Elasticity: Theory Application and Numerics, Academic Press, 2004.
ME341	HEAT AND MASS TRANSFER	3-0-0-0-4	Introduction. One dimensional and Two dimensional Steady and Transient Conduction.Forced Convection over a flat plate and inside tubes. Natural Convection over a vertical flatplate. Mass Transfer. Boiling and Condensation. Heat Exchangers. Thermal Radiation. Heat Transfer Applications. **Course Reference**: 1. Fundamentals of Heat and Mass Transfer by Frank P. Incropera and David P. Dewitt (4th ed.,John Wiley & Sons, New York, 1998); 2. Heat Transfer by J.P.Holman (9th ed., Tata McGrawHill Edition, New Delhi, 2004); 3. Heat Transfer by P.S.Ghoshdastidar (Oxford University Press India, New Delhi, 2004); 4. Heat and Mass Transfer by Yunus A. Cengel (3rd ed., Tata McGrawHill Edition, New Delhi,2007); 5. Solar Energy by S. P.Sukhatme (2nd ed., Tata McGrawHill, New Delhi, 1996)
ME341A	HEAT & MASS TRANSFER	3-0-1-0-10	Introduction. Onedimensional and Twodimensional Steady and Transient Conduction.Forced Convection over a flat plate and inside tubes. Natural Convection over a vertical flatplate. Mass Transfer. Boiling and Condensation. Heat Exchangers. Thermal Radiation. HeatTransfer Applications. **Course Reference**: 1. Fundamentals of Heat and Mass Transfer by Frank P. Incropera and David P. Dewitt (4th ed.,John Wiley & Sons, New York, 1998); 2. Heat Transfer by J.P.Holman (9th ed., Tata McGrawHill Edition, New Delhi, 2004); 3. Heat Transfer by P.S.Ghoshdastidar (Oxford University Press India, New Delhi, 2004); 4. Heat and Mass Transfer by Yunus A. Cengel (3rd ed., Tata McGrawHill Edition, New Delhi,2007); 5. Solar Energy by S. P.Sukhatme (2nd ed., Tata McGrawHill, New Delhi, 1996)
ME351	DESIGN OF MACHINE ELEMENTS	3-0-2-0-4	Introduction to design of systems and machine elements; Modes of failure, strength, stiffness and stability; Failure theories; Fatigue failure; Probabilistic approach todesign; Design of Bolted and Welded joints, Helical compression springs and leaf springs, Spurand Helical gear sets; Selection of Rolling contact bearings; Design of shafts. Lab sessions: Detailed design of the above machine elements starting functional specifications to final sizing; Design of a subsystem involving multiple machine elements. Introduction to use of

			techniqueslike FEM for design. **Course Reference**: 1. Mechanical Engineering Design by E. Shigley, C.R. Mischke & R.G. Budynas, McGraw Hill; 2. Machine elements in Mechanical Design by R.L. Mott, Prentice Hall; 3. Mechanical Design by P. Childs, Elsevier; 4. Fundamentals of Machine Component Design by R. C. Uvinall & K. M. Marshek, Wiley; 5. Machine Design by R.L. Norton
ME351A	DESIGN OF MACHINE ELEMENTS	2-0-2-0-8	Introduction to design of systems and machine elements; Modes of failure, strength, stiffness and stability; Failure theories; Fatigue failure; Probabilistic approach todesign; Design of Bolted and Welded joints, Helical compression springs and leaf springs, Spurand Helical gear sets; Selection of Rolling contact bearings; Design of shafts. Lab sessions: Detailed design of the above machine elements starting functional specifications to final sizing; Design of a subsystem involving multiple machine elements. Introduction to use of techniques like FEM for design. **Course Reference**: 1. Mechanical Engineering Design by E. Shigley, C.R. Mischke & R.G. Budynas, McGraw Hill; 2. Machine elements in Mechanical Design by R.L. Mott, Prentice Hall; 3. Mechanical Design by P. Childs, Elsevier; 4. Fundamentals of Machine Component Design by R. C. Uvinall & K. M. Marshek, Wiley; 5. Machine Design by R.L. Norton
ME352	THEORY OF MECHANISMS & MACHINES	3-0-0-0-4	Kinematic pairs, diagrams and inversion. Mobility and range of movement. Displacement, Velocity and Acceleration analysis of planar linkages. Dimensional synthesis formotion, path and function generation. Dynamic force analysis, flywheels. Inertia forces andbalancing for rotating and reciprocating machines. Cam mechanisms, Cam profile synthesis. Gears, and gear trains. Theory of Mechanisms and Machines by Ghosh and Mallik (EWP).
ME352A	THEORY OF MECHANISMS & MACHINES	2-0-1-0-7	Kinematic pairs, diagrams and inversion. Mobility and range of movement. Displacement, velocity and acceleration analysis of planar linkages. Dimensional synthesis formotion, path and function generation. Dynamic force analysis, flywheels. Inertia forces and balancing for rotating and reciprocating machines. Cam mechanisms, Cam profile synthesis. Gears and gear trains. Theory of Mechanisms and Machines by Ghosh and Mallik (EWP).
ME353	DYNAMICS AND VIBRATION OF MACHINERY	3-0-0-0-4	Three-dimensional motion of rigid bodies kinematics and kinetics. Gyrodynamics.Vibrations of single, two and multiple degrees of freedom systems, free andforced vibrations; Time and frequency domain analysis, Free vibration of one-dimensional continuous systems, approximate methods.
ME354	VIBRATION & CONTROL	3-0-0-1-4	Introduction to modeling of dynamical systems. Single Degree of Freedom Systems Free undamped vibration, Free damped vibration, Forced vibration, Transmissibility, Convolution method, Mechanisms of damping. Two Degree of Freedom System (undamped vibration only) Free and forced vibrations, vibration absorber. Multi Degree of Freedom Systems (undamped and proportional damping) Matrix methods, Modal analysis. Approximate Methods. Vibration of continuous systems (free vibration only). Introduction to controls. Review

			of Laplace transforms. Block diagrams. Root locus method. Stability; RouthHurwith criterion, Nyquist plots. Bode plots. Controller performance and types. Steady State Errors and constants. Types of feedback control systems Derivative error compensation, Integral error compensation, Proportional error compensation. Modern control. Digital control. **Course Reference**: 1. Theory of Vibrations. W. T. Thomson, Prentice Hall; 2. Control Systems Engineering. N. S. Nise, john Wiley & Sons; 3. Vibration Problems in Engineering. W. Weaver, S. P. Timoshenko and D. H. Young, johnWiley & Sons; 4. Mechanical Vibration.). P. Den Hartog, Dover Publications; 5. Feedback Control of Dynamic Systems. G. Franklin,). D. Powell, and A. EmamiNaeini, Prentice Hall; 6. Modern Control Engineering. K. Ogata, Prentice Hall.
ME354A	VIBRATION & CONTROL	3-0-1-0-10	Introduction to modeling of dynamical systems. Single Degree of Freedom Systems Free undamped vibration, Free damped vibration, Forced vibration, Transmissibility, Convolution method, Mechanisms of damping. Two Degree of Freedom System (undampedvibration only) Free and forced vibrations, vibration absorber. Multi Degree of Freedom Systems (undamped and proportional damping) Matrix methods, Modal analysis. Approximate Methods.Vibration of continuous systems (free vibration only). Introduction to controls. Review of Laplace transforms. Block diagrams. Root locus method. Stability-RouthHurwith criterion, Nyquist plots. Bode plots. Controller performance and types. Steady State Errors and constants. Types of feedback control systems Derivative error compensation, Integral error compensation, Proportional error compensation. Modern control. Digital control. **Course Reference**: 1. Theory of Vibrations. W. T. Thomson, Prentice Hall; 2. Control Systems Engineering. N. S. Nise, john Wiley & Sons; 3. Vibration Problems in Engineering. W. Weaver, S. P. Timoshenko and D. H. Young, johnWiley & Sons; 4. Mechanical Vibration.). P. Den Hartog, Dover Publications; 5. Feedback Control of Dynamic Systems. G. Franklin,). D. Powell, and A. Emami Naeini, Prentice Hall; 6. Modern Control Engineering. K. Ogata, Prentice Hall.
ME359	INTERNAL COMBUSTION ENGINES	3-0-0--4	Classification, Construction, Valve arrangements. Fuels, Fuel air cycle. Combustion, Effect of engine variables, Combustion chambers, Carburation and fuel injection, Knocking. Engine cooling, Friction and lubrication Super charging. Wankel engine testing and performance. Pollution.
ME359A	INTERNAL COMBUSTION ENGINES	3-0-0-0-9	Classification, Construction, Valve arrangements. Fuels, Fuel air cycle. Combustion, Effect of engine variables, Combustion chambers, Carburation and fuel injection, Knocking. Engine cooling, Friction and lubrication Supercharging. Wankel engine testing and performance. Pollution.
ME361	MANUFACTURING TECHNOLOGY	3-0-0-0-4	Introduction to manufacturing processes and system concept and itsevolution; Metal casting: Solidification Mechanism, Gating and Riser Design, Defects and Product Design; Metal Forming: Fundamentals of Plasticity, Force Equilibrium Method,Forging/upsetting, Drawing, Extrusion, Deep Drawing and Bending, Defects; Machining: Tool Specifications,

			Orthogonal and Oblique cutting, Tool wear and Tool Life, Economics ofMachining; Shaping processes for Plastics and Tool Design; joining Processes; UnConventional Material Removal Processes: ECM, EDM, LBM and jet Machining; Rapid Prototyping andTooling; Microfabrication technologies; Metrology and Selection of Manufacturing Processes. **Course Reference**: 1. Ghosh, A., Mallik, A.K., Manufacturing Science (2nd edition}, EastWest Press, 2010; 2. Lal, G.K., Introduction to Machining Science (2nd edition}, New Age International publishers, 2009; 3. Groover, M.P, Fundamentals of Modern Manufacturing (2nd edition}, john Wiley; 4. Kalpakjian, S., Schmid, S.C., Manufacturing Engineering and Technology, Pearson Education; 5. Galyer, j.F.W., Shotbolt, C.R., Metrology for Engineers, ELBS
ME361A	MANUFACTURING SCIENCE & TECHNOLOGY	3-0-1-0-10	Introduction to manufacturing processes and system concept and itsevolution; Metal casting: Solidification Mechanism, Gating and Riser Design, Defects andProduct Design; Metal Forming: Fundamentals of Plasticity, Force Equilibrium Method,Forging/upsetting, Drawing, Extrusion, Deep Drawing and Bending, Defects; Machining: Tool Specifications, Orthogonal and Oblique cutting, Tool wear and Tool Life, Economics of Machining; Shaping processes for Plastics and Tool Design; joining Processes; UnConventional Material Removal Processes: ECM, EDM, LBM and jet Machining; Rapid Prototyping andTooling; Microfabrication technologies; Metrology and Selection of Manufacturing Processes. **Course Reference**: 1. Ghosh, A., Mallik, A.K., Manufacturing Science (2nd edition}, EastWest Press, 2010; 2. Lal, G.K., Introduction to Machining Science (2nd edition}, New Age International publishers, 2009; 3. Groover, M.P, Fundamentals of Modern Manufacturing (2nd edition}, john Wiley; 4. Kalpakjian, S., Schmid, S.C., Manufacturing Engineering and Technology, Pearson Education; 5. Galyer, j. F.W., Shotbolt, C.R., Metrology for Engineers, ELBS.
ME371	MECHANICAL ENGINEERING LAB-I	0-0-6-0-4	Experimentation in machine dynamics, Materials, Manufacturing Sciences and Fluid mechanics.
ME374	MECHANICAL ENGG. RESEARCH	----4	To learn about a topic in depth through independent study under the guidance of a faculty member from the department. Based on an Original Research Project/design project/experimental project.
ME398A	UNDER GRADUATE PROJECT I	0-0-4-0-4	UG PROJECT (UGPI)
ME399A	MECHANICAL ENGINEERING COMMUNICATION SKILLS	0-0-0-2-2	MECHANICAL ENGINEERING COMMUNICATION SKILLS
ME401	ENERGY SYSTEMS - II	3-0-0-0-4	Introduction: General Theory and Classification of Turbomachines; Similarity and Dimensional Analysis; Two-dimensional Cascade Theory; Axial and Radial Flow Machines: Turbines, Compressors and Fans; Gas Turbine Power Plant Cycles; Thermal Power plant: Flow through

			Nozzleand Steam Turbines; Hydraulic Machines: Pelton, Francis and Kaplan Turbines; Pump and Cavitation. **Course Reference**: 1. S. L. Dixon and C. A. Hall, Fluid Mechanics and Thermodynamics of Turbomachinery, Elsevier,Sixth Edition, 2010; 2. H. Cohen, G. F. C. Rogers and H. I. H. Saravanamuttoo, Gas Turbine Theory, Addison WesleyLongman Ltd, Fourth Edition, 1996; 3. S.M.Yahya, Turbines, Compressor and Fan, Tata McGrawHill, Second Edition, 2003; 4. B.Lakshminarayana, Fluid Dynamics and Heat Transfer ofTurbomachinery, John Wiley and Sons,Inc, 1996.
ME401A	ENERGY SYSTEMS-II	3-0-1-0-10	Introduction: General Theory and Classification of Turbomachines; Similarity and Dimensional Analysis; Two-dimensional Cascade Theory; Axial and Radial Flow Machines: Turbines, Compressors and Fans; Gas Turbine Power Plant Cycles; Thermal Power plant: Flow through Nozzleand Steam Turbines; Hydraulic Machines: Pelton, Francis and Kaplan Turbines; Pump and Cavitation. **Course Reference**: 1. S. L. Dixon and C. A. Hall, Fluid Mechanics and Thermodynamics of Turbomachinery, Elsevier,Sixth Edition, 2010; 2. H. Cohen, G. F. C. Rogers and H. I. H. Saravanamuttoo, Gas Turbine Theory, Addison WesleyLongman Ltd, Fourth Edition, 1996; 3. S.M.Yahya, Turbines, Compressor and Fan, Tata McGrawHill, Second Edition, 2003; 4. B.Lakshminarayana, Fluid Dynamics and Heat Transfer of Turbomachinery, John Wiley and Sons,Inc, 1996.
ME451	PROJECT - I	0-0-6-0-4	Project work involving the analysis, synthesis, material/component selection and detailed design of a mechanical system including the preparation of working drawings. The systemmay be integrated with electronics, electrical, hydraulic and other systems. Projects may be selected by students from any of the four specific areas (or a combination there of) Fluid mechanics and Thermal sciences, Solid Mechanics and Design, Manufacturing Science and Robotics and/or any other related mechanical system(s).
ME451A	ME PROJECT-1	0-0-0-0-9	Project work involving the analysis, synthesis, material/component selection and detailed design of a mechanical system including the preparation of working drawings. The systemmay be integrated with electronics, electrical, hydraulic and other systems. Projects may beselected by students from any of the four specific areas (or a combination there of) Fluid mechanics and Thermal sciences, Solid Mechanics and Design, Manufacturing Science and Robotics and/or any other related mechanical system(s).
ME452	PROJECT II	0-0-4-0-2	PROJECT II
ME452	PROJECT II	0-0-4-0-2	Fabrication of a prototype and appropriate modification in the design (if necessary) to meet the qualitative and quantitative performance parameters as envisaged in the Project I
ME452A	PROJECT II	0-0-6-0-6	Fabrication of a prototype and appropriate modification in the design (if necessary) to meet the qualitative and quantitative performance parameters as envisaged in the Project I

ME453	AUTOMATION AND CONTROL	3-0-0-0-4	Modeling, Analysis, and Simulation of Dynamic System; Mechanical, electronic, electrohydraulic and electomechanical systems; Stepper and Servomotors; useof MATLAB; State Space, laplace and frequency domain system behaviour; Bode, Nyquist, and root locus plots; open and closed loop control systems; stability and sensitivity; PID, Phase lag and Phase lead compensation; Sampled datasystems and Digtal controllers; DA/AD converters; Microprocessors; Sensors and actuators; interfacing with computers.
ME461	MANUFACTURING SYSTEMS	3-0-0-0-4	Introduction to manufacturing, Manufacturing system concept. Manufacturing-automation, FMS, CIMS, Flow lines and assembly systems, Automated storage /retrieval systems, AGV. Introduction to CAD/CAM, NC, CNC, DNC, Adaptive control. Manual andcomputer assisted part programming. Introduction to robots and their application inmanufacturing. Process planning and Computer Aide Process planning. Group Technology, Opitz System and GT benefits. Material Management and Inventory control, MRP and MRP II. Just in time (JIT) and Lean manufacturing. Introduction to quality assurance and control, Statistical Quality Control, control charts, sampling. Total Quality Management. Manufacturing system simulation. **Course Reference**: 1. Computer Integrated Design and Manufacturing by Nanua Singh, john Wiley; 2. Computer Aided Manufacturing by Chang, Wysk, Wang, Prentice Hall; 3. Computer Aided Manufacturing by Rao, Tewari, Kundra, TMH
ME461A	MANUFACTURING SYSTEMS	3-0-0-0-9	Introduction to manufacturing, Manufacturing system concept. Manufacturing Automation, FMS, CIMS, Flow lines and assembly systems, Automated storage /retrieval systems, AGV. Introduction to CAD/CAM, NC, CNC, DNC, Adaptive control. Manual andcomputer assisted part programming. Introduction to robots and their application inmanufacturing. Process planning and Computer Aide Process planning. Group Technology, Opitz System and GT benefits. Material Management and Inventory control, MRP and MRP II. Just in time (JIT) and Lean manufacturing. Introduction to quality assurance and control, Statistical Quality Control, control charts, sampling. Total Quality Management. Manufacturing system simulation. **Course Reference**: 1. Computer Integrated Design and Manufacturing by Nanua Singh, john Wiley; 2. Computer Aided Manufacturing by Chang, Wysk, Wang, Prentice Hall; 3. Computer Aided Manufacturing by Rao, Tewari, Kundra, TMH
ME471N	MECHANICAL ENGINEERING LAB	0-0-6--4	Experimentation in automation and control, Solid Mechanics, Heat transfer, Energy conversion.
ME600	COMMUNICATION SKILLS FOR ENGINEERS	1-1-0--0	COMMUNICATION SKILLS FOR ENGINEERS
ME600A	COMMUNICATION SKILLS FOR ENGINEERS	2-0-0-0-6	COMMUNICATION SKILLS FOR ENGINEERS
ME601A	LANGUAGE AND STYLE OF		

	SCHOLARLY COMMUNICATION		
ME613	THERMAL ENVIROMENTAL CONTROL	3-0-0-0-4	Moist air and psychrometric processes. Physiological principles of thermal comfort, calculation of cooling and heating loads; ADP determination, solar radiation and shading devices, duct design; Heat and mass transfer in air washers, cooling towers, finned heat exchangers; Air dehumidification.
ME613A	THERMAL ENVIROMENTAL CONTROL	3-0-0-0-9	Moist air and psychrometric processes. Physiological principles of thermal comfort, calculation of cooling and heating loads; ADP determination, solar radiation and shading devices, duct design; Heat and mass transfer in air washers, cooling towers, finned heat exchangers; Air dehumidification.
ME617	ADVANCED THEORY OF TURBOMACHINER Y	3-0-0--4	The equations of motion in rotating coordinate system, effects of Coriolis and Centrifugal forces, energy equation, classification of turbo machines; two dimensional cascade theory and experimental results; two dimensional flow analysis of axial impellers; three dimensional flow in axial turbo machines, radial equilibrium, secondary flows and loss estimation; offdesign performance; radialand mixed flow machines; multistage axial compressors and turbines; prediction of stage performance and stacking; rotating stall and surge; turbine blade heat load and blade cooling;
ME620A	RADIATION INTERACTION, DETECTION, AND SHIELDING-THEORY ON NUCLEAR MEASUREM	3-0-0-0-9	Applications of Radiation. Half Life Determination. Radiation Dose Levels and Calculation: Inverse Square Law Verification, ALARA Principle, Linearnothreshold model. Basic Principles of Radiation Detection. Gamma Ray Interactions: photoelectric, Compton scattering, pair production Empirical calculation of crosssections, Linear Attention Coefficient Measurement. Evaluation of GM Detector Characteristics: Plateau determination, Dead time calculations, paralyzable and nonparalyzable detectors. Measurements and Counting Statistics for Error Evalution Limits. Ionizing radiation and detection, Neutron and special nuclear material (SNM) detection for security applications. Mechanisms of neutron interaction: capture, scientillation etc. Scintillation detectors, Capture detectors, Fission chambers. Semiconductor Detectors. Pulse shaping and signal processing. Radiation detection and shielding methods for safety at various nuclear facilities. Measuring gamma dose and shielding calculations. Measuring neutron spectrum and dose and shielding calculations. Measuring other forms of radiation, dose and shielding calculations. Principles of particle accelerator and measurements on the 1.7 MeV TANDETRON* OR Instrumentation and controls used in existing and advanced nuclear power plants **Course Reference**: 1. G.F. Knoll, Radiation Detection and Measurements, John Wiley & Sons, Hoboken, New Jersey (2010); 2. S. S. Kapoor and V.S. Ramamurthy, Nuclear Radiation Detectors, Wiley Eastern Limited (1986); 3. K.S. Ram, Nuclear Measurements and Techniques, Affiliated West Press, New Delhi (1986)
ME621	INTRODUCTION TO SOLID	3-0-0--4	I. Introduction. 1. Review of strength of Materials and its limitations. II. Mathematical Preliminaries. 1.Vector and tensor

	MECHANICS		calculus. 2. Indicial notationIII. Strains. 1. Definition of small strain, StrainDisplacement relations in 3D, Physical interpretation of strain components, Principal Strains. IV. Stress and equilibrium. 1.Stress components in 3D and their physical interpretations. 2. Principal Stresses. 3. Cauchys principle and derivations of stress equilibrium equations in stress components. V. Constitutive law, Naviers equations, compatibility. 1. Constitutive law for general linear elastic solid, Discussions on isotropic, orthotropic and transversely isotropic solid. 2. Naviers equations. 3. Stress and displacement approaches. 4.Compatibility equations. VI. Formulation of boundary value problems and solution methods. 1. Formulation of boundary value problems. 2.Plane Problems plane stress, plane strain, antiplane shear (also in axisymmetric coordinates) 3. Examples of plane problems: Stress function approach, Series solutions. 4.Fourier transform methods with examples. 5. Superposition principle: Flamants solutions; Kelvins solution; Boussinesqs solution. VII. Additional topics a few topics to be selected from below. 1.Further examples: Torsion of prismatic shaft; Contact problems; Wedge problems; Dislocations and inclusions; Cracks; Thinfilm problems. 2. Further methods: Advanced transform methods; Complex variable techniques; Potential methods. 3.Further ideas: Energy methods; Numerical approaches; Finite elements; Eigenstrains; Micromechanics. **Course Reference**: 1. Elasticity, J. R. Barber; 2. The Linearized Theory of Elasticity, W. L. Slaughter; 3. Continuum Mechanics for Engineers, G. T. Mase and G. E. Mase; 4. Theory of Elasticity, S. Timoshenko and J. N. Goodier; 5. Elasticity: Theory, Applications and Numerics, M. H. Sadd6.Applied Mechanics of Solids, A. Bower
ME621A	INTRODUCTION TO SOLID MECHANICS	3-0-0-0-9	I. Introduction. 1. Review of strength of Materials and its limitations. II. Mathematical Preliminaries. 1.Vector and tensor calculus. 2. Indicial notation-III. Strains. 1. Definition of small strain, Strain Displacement relations in 3D, Physical interpretation of strain components, Principal Strains. IV. Stress and equilibrium. 1.Stress components in 3D and their physical interpretations. 2. Principal Stresses. 3. Cauchys principle and derivations of stress equilibrium equations in stress components. V. Constitutive law, Naviers equations, compatibility. 1. Constitutive law for general linear elastic solid, Discussions on isotropic, orthotropic and transversely isotropic solid. 2. Naviers equations. 3. Stress and displacement approaches. 4.Compatibility equations. VI. Formulation of boundary value problems and solution methods. 1. Formulation of boundary value problems. 2.Plane Problems plane stress, plane strain, antiplane shear (also in axisymmetric coordinates) 3. Examples of plane problems: Stress function approach, Series solutions. 4.Fourier transform methods with examples. 5. Superposition principle: Flamants solutions; Kelvins solution; Boussinesqs solution. VII. Additional topics a few topics to be selected from below. 1.Further examples: Torsion of prismatic shaft; Contact problems; Wedge problems; Dislocations and inclusions;

			Cracks; Thinfilm problems. 2. Further methods: Advanced transform methods; Complex variable techniques; Potential methods. 3.Further ideas: Energy methods; Numerical approaches; Finite elements; Eigenstrains; Micromechanics. **Course Reference**: 1. Elasticity, J. R. Barber; 2. The Linearized Theory of Elasticity, W. L. Slaughter; 3. Continuum Mechanics for Engineers, G. T. Mase and G. E. Mase; 4. Theory of Elasticity, S. Timoshenko and J. N. Goodier; 5. Elasticity: Theory, Applications and Numerics, M. H. Sadd; 6. Applied Mechanics of Solids, A. Bower
ME622	THEORY OF ELASTICITY	3-0-0--4	Analysis of stress and strain; Equilibrium, Compatibility and constitutiveequations; Plane problems; Stress functions; Applications; Complex potentialsin two dimensional and axisymmetric problems; Variational methods; Anisotropic elasticity; Finite deformation elasticity.
ME622A	INTRODUCTION TO CONTINUUM MECHANICS	3-0-0-0-9	Analysis of stress and strain; Equilibrium, Compatibility and constitutive equations; Plane problems; Stress functions; Applications; Complex potentialsin two dimensional and axisymmetric problems; Variational methods; Anisotropic elasticity; Finite deformation elasticity.
ME623	FINITE ELEMENT METHODS IN ENGINEERING MECHANICS	3-0-0--4	Introduction to ID FEM. Problems in structural mechanics using two dimensional elements; Plane stress, plane strain, axisymmetric analysis; Three- dimensional stress analysis; Shell analysis; Solution of heat conduction, fluid flow, vibration, stability, and nonlinear, large scale systems.
ME623A	FINITE ELEMENT METHODS IN ENGINEERING MECHANICS	3-0-0-0-9	Introduction to ID FEM. Problems in structural mechanics using two dimensional elements; Plane stress, plane strain, axisymmetric analysis; Three- dimensional stress analysis; Shell analysis; Solution of heat conduction, fluid flow, vibration, stability, and nonlinear, large scale systems.
ME625	APPLIED DYNAMICS AND VIBRATIONS	3-0-0--4	Review of single degree of freedom systems; Generalised coordinates, constraints, virtual work; Lagranges equation; Continuous systems; strings, beams; RaleighRitz and Galerkins methods; Dynamics of rigid bodies in three dimensions; Euler angles; Eulers equations of motion, Gyrodynamics.
ME625A	APPLIED DYNAMICS AND VIBRATIONS	3-0-0-0-9	Part I: NewtonEuler mechanics. 1. Mathematical preliminaries: Coordinate systems, Vectors, Tensors, Outer product; Coordinate transformation. 2. Rotating frames; Rotation tensor; Euler angles; Angular velocity. 3. Rigidbody kinematics; Fiveterm acceleration formula; Examples. 4. Rigidbody kinetics: Linear Momentum; Angular momentum; Inertia tensor; Kinetic energy. 5. Rigidbody kinetics: Balance laws; Governing equations; Eulers equations. 6. Examples: Rigid body in free space; Gyroscopes. Part II: Analytical mechanics. 1. Generalized coordinates; Constraints; Degrees of freedom. 2. Principal of virtual work in statics: Virtual displacements; Virtual work; Constraint forces; Workless constraints; Principal of virtual work; Lagrange multipliers; Equilibria and stability of conservative systems; Examples. 3. Dynamics: dAlemberts principal; Lagranges equations of motion for holonomic and nonholonomic systems; 4. Examples: Rigid bodies; aplygins sleigh. 5. Conservative systems. Legendre transformation;

			Hamiltonian mechanics; Energy theorem; Examples. Part III: Vibrations. 1. Single degree of freedom system: free, damped, forced. 2. Convolution integral. 3. Twodegree of freedom systems: Normal modes; 4. Extension to multidegree of freedom systems. 5. Examples. 6. Laboratory demos/sessions: Summary: Mathematical preliminaries: Vectors; Tensors; Coordinate transformations. NewtonEuler Mechanics: Rotation; Three dimensional Rigidbody kinematics and dynamics; Specialisation to two dimensions; Gyroscopes. Analytical Mechanics: Virtual work; Lagrange multipliers; Lagranges equations; Holonomic and nonholonomic systems; Hamiltonian mechanics. Vibrations: Free, damped and forced singledegree of freedom system; Two degree of freedom system; Normal modes; Multidegree of freedom systems; Lab demos/sessions. **Course Reference**: 1. Greenwood, D. T. 1987. Principles of Dynamics 2nd edition. Pearson Education; 2. Beatty, M. F. 1986. Principles of Engineering Mechanics: Part I, II. Springer; 3. Meirovitch, L. 1986. Elements of Vibration Analysis 2nd edition. McGraw Hill Education (India); 4. Meirovitch, L. 2010 Methods of Analytical Mechanics. Dover publications; 5. Thomson, W. T. 2002. Theory of Vibrations with Applications 3rd edition. CBS publishers; 6. Hartog, D. 1985. Mechanical Vibrations. Dover publishers; 7. Lanczos, C. 1986. The Variational Principles of Mechanics 4th edition. Dover publications; 8. Sharma, I. & S. S. Gupta. 2016. Understanding Rigid Body Dynamics. (under preparation)
ME626	VIBRATION OF CONTINUOUS SYSTEM	3-0-0--4	Vibration of discrete systems with single and multi degree of freedom. Hamiltons principle, Langranges equations. Longitudinal vibration of bars, lateral vibration of straight and curved beams, vibration of membranes and plates, free and forced vibrations. Effect of damping. Wave motion in continuous systems.
ME626A	VIBRATION OF CONTINUOUS SYSTEMS	3-0-0-0-9	Vibration of discrete systems with single and multi degree of freedom. Hamiltons principle, Langranges equations. Longitudinal vibration of bars, lateral vibration of straight and curved beams, vibration of membranes and plates, free and forced vibrations. Effect of damping. Wave motion in continuous systems.
ME627	NON-LINEAR VIBRATION	3-0-0--4	Phase space, singular points, limit cycle; Analytical methods, perturbation techniques, equivalent linearization; Duffings equation, jump phenomenon, Van der Pol equation. Stability criterion; Floquets theory, Hills and Mathieus equations, Bifurcation and chaos.
ME627A	NONLINEAR VIBRATION	3-0-0-0-9	Phase space, singular points, limit cycle; Analytical methods, perturbation techniques, equivalent linearization; Duffings equation, jump phenomenon, Van der Pol equation. Stability criterion; Floquets theory, Hills and Mathieus equations, Bifurcation and chaos.
ME630	NUMERICAL FLUID FLOW AND HEAT TRANSFER	3-0-0--4	ODE, matrix methods, root finding. Classification of PDE, finite differences, Steady and unsteady conduction, explicit and implicit method, advection diffusion problems, upwinding, boundary layers, NavierStokes equations, MACand SIMPLE

			finite element method for heat conduction.
ME630A	COMPUTATIONAL FLUID DYNAMICS AND HEAT TRANSFER	3-0-0-0-9	ODE, matrix methods, root finding. Classification of PDE, finite differences, Steady and unsteady conduction, explicit and implicit method, advection diffusion problems, upwinding, boundary layers, NavierStokes equations, MACand SIMPLE finite element method for heat conduction.
ME631	VISCOUS FLOW THEORY	3-0-0--4	Stress deformation relations, Navier Stokes equation, exact solutions, two dimensional and axisymmetric boundary layers, Separation, Compressible boundary layers, Elements of stability theory, Turbulent flow: logarithmic law of the wall, effect of wall roughness, two and three equation models, fluid solid interaction.
ME631A	VISCOUS FLOW THEORY	3-0-0-0-9	Introduction: Fluid Properties, Definition of Continuum, Examples of Viscous Flow Phenomena, Laminar and Turbulent Flow, Vector and Tensor notation, Lagrangian/Eulerian Methods,Streamline, Path line, Streak line,Material Derivative and acceleration, Strain Rate, Translation, Rotation and Distortion of Fluid Element, Vorticity and Circulation.Fundamental Equations of Viscous Flow: Conservation of Mass, Momentum and Energy,Finite Volume Approach, Derivation of Continuity Equation: conservative and non conservative form, Derivation of NavierStokes (NS) equations for Compressible Flow, Stokes Hypothesis. Incompressible form of NS equations. Exact Solutions: Parallel Flow in a Straight Channel, Couette Flow, Lubrication Theory, HagenPoiseuille Flow, Unsteady Parallel Flow, Stokes Problems, Similarity Solution and Creeping Flow, Complex variable and Potential flow. Boundary Layer Theory: Derivation of 2D Boundary Layer Equations, Displacement, Momentum and Energy Thickness, Order of Magnitude Analysis, Shape Factor, MomentumIntegral Approach, Boundary Layer Separation, Effect of Pressure Gradient, Boundary Layer Control by Suction and Blowing, BlassiusSolution of Boundary Layer Equation, Krmn Pohlhausen Method for NonZero Pressure Gradient, Holstenand Bohlen Method (Modified Pohlhausen Method), Waltzs Quadrature Formula and Example Problems.
ME634	ADVANCED COMPUTATIONAL FLUID DYNAMICS	3-0-0-0-4	Discretisation procedure in Finite difference and Finite volume. Navier Stokes, Energy equations. Staggered rectilinear grids. Explicit methods: MAC, SMAC.Implicit Methods, SIMPLE and SIMPLER. Matrix methods, conjugate gradient method, strongly Implicit Procedure. Grid Generation: Algebraic, Transfinite, Poisson equation methods. Finite difference Navier Stokes solution on nonorthogonal grids, transformation. Collocated grids. Finite volume methods on nonorthogonal grids. Turbulence modelling, ke modelling
ME634A	ADVANCED COMPUTATIONAL FLUID DYNAMICS	3-0-0-0-9	Discretisation procedure in Finite difference and Finitevolume. Navier Stokes, Energy equations. Staggered rectilinear grids. Explicit methods: MAC, SMAC.Implicit Methods, SIMPLE and SIMPLER. Matrix methods, conjugate gradient method, strongly Implicit Procedure. Grid Generation: Algebraic, Transfinite, Poisson equation methods. Finite difference Navier Stokes solution on nonorthogonal grids, transformation.

			Collocated grids. Finite volume methods on nonorthogonal grids. Turbulence modelling, ke modelling
ME639	LIQUID VAPOUR PHASE CHANGE PHENOMENA	3-0-0--4	1st Term (14 hours), 2nd Term (14 hours), 3rd Term (14 hours) Introduction to two phase flow and heat transfer technology Liquid vapor phase change phenomena, Interfacial tension, Wetting phenomenon, Contact angles, Transport effects, Dynamic behavior of interfaces, Phase stability and nucleation Two phase flow fundamentals, Flow patterns and map representation, Development of homogeneous, separated flow and drift flux models, Flooding mechanismso Boiling Fundamentals, Homogeneous and heterogeneous nucleation, Pool boiling and convective flow boiling, Heat transfer and CFH mechanisms, Enhancement techniqueso Condensation fundamentals, External and internal condensation , Film condensation theory, Dropwise condensation theory , Enhancement techniqueso Experimental techniques, Practical boundary conditions, Void fraction measurement techniques, Flow visualization techniques, Contact angle/Surface tension measurement, Conventional thermometry , Limitations, Data reduction, Application examples Application of twophase t1ow and heat transfer, Theory and operation of Boilers/Evaporators and condensers for Nuclear/Power/RAC industry, Electronics thermal management, Latent heat storage devices, Gravity assisted thermosyphons/ Vapor chambers, Conventional heat pipes, Micro heat pipes, Pulsating heat pipes, Capillary pumped loops/ Loop heat pipes, Micro two phase heat exchangers Special related topics: for example, static and dynamic instabilities, microscale boiling and condensation, atomistic nucleation models, microgravity boiling, microfabrication/ integration techniques, contact resistance, surface roughness, Leidenfrost phenomena, etc. (i) Liquid Vapor Phase Change Phenomena by Van P. Carey (Taylor & Francis) (ii) Convective Boiling And Condensation by Collier John (Oxford Engineering Science) (iii) Heat Transfer Characteristics in Boiling and Condensation by Karl Stephan (Springer) (iv) Twophase Flow and Heat Transfer P. B. Whalley (Oxford Engineering Science) (v) One Dimensional TwoPhase Flow G. B. Wallis (McGraw Hill) (vi) Heat Pipe Science and Technology by Amir Faghri (Taylor and Francis) (vii) Heat Pipe Technology and Applications by J . P. Peterson (John Wiley & Sons) (viii) Heat Transfer A practical approach by Yunus Cengel (Tata McGraw Hill) (ix) Heat Transfer Incropera and Dewitt (John Wiley and Sons).
ME639A	LIQUID-VAPOUR PHASE CHANGE TECHNOLOGY	3-0-0-0-9	1st Term (14 hours), 2nd Term (14 hours), 3rd Term (14 hours) Introduction to two phase flow and heat transfer technology Liquid vapor phase change phenomena, Interfacial tension, Wetting phenomenon, Contact angles, Transport effects, Dynamic behavior of interfaces, Phase stability and nucleation. Two phase flow fundamentals, Flow patterns and map representation, Development of homogeneous, separated flow and drift flux models, Flooding mechanismso Boiling Fundamentals, Homogeneous and heterogeneous nucleation, Pool boiling and convective flow boiling, Heat transfer and CFH mechanisms, Enhancement techniqueso Condensation

			fundamentals, External and internal condensation , Film condensation theory, Dropwise condensation theory , Enhancement techniqueso Experimental techniques, Practical boundary conditions, Void fraction measurement techniques, Flow visualization techniques, Contact angle/Surface tension measurement, Conventional thermometry , Limitations, Data reduction, Application examples Application of two phase flow and heat transfer, Theory and operation of Boilers/Evaporators and condensers for Nuclear/Power/RAC industry, Electronics thermal management, Latent heat storage devices, Gravity assisted thermosyphons/ Vapor chambers, Conventional heat pipes, Micro heat pipes, Pulsating heat pipes, Capillary pumped loops/ Loop heat pipes, Micro twophase heat exchangers Special related topics: for example, static and dynamic instabilities, microscale boiling and condensation , atomistic nucleation models, microgravity boiling, microfabrication/ integration techniques, contact resistance, surface roughness, Leidenfrost phenomena, etc. (i) Liquid Vapor Phase Change Phenomena by Van P. Carey (Taylor & Francis) (ii) Convective Boiling And Condensation by Collier John (Oxford Engineering Science) (iii) Heat Transfer Characteristics in Boiling and Condensation by Karl Stephan (Springer) (iv) Twophase Flow and Heat Transfer P. B. Whalley (Oxford Engineering Science) (v) One Dimensional Two Phase Flow G. B. Wallis (McGraw Hill) (vi) Heat Pipe Science and Technology by Amir Faghri (Taylor and Francis)(vii) Heat Pipe Technology and Applications by J . P. Peterson (John Wiley & Sons) (viii) Heat Transfer A practical approach by Yunus Cengel (Tata McGraw Hill) (ix) Heat Transfer Incropera and Dewitt (John Wiley and Sons)
ME641	CONDUCTION AND RADIATION	3-0-0--4	Conduction: Steady and unsteady problems and their solutions in cartesian, cylindrical and spherical coordinates. Separation of variables. Duhamels theorem. Laplace Transform. Problems involving change of phase. Inverse heat conduction, Microscale heat transfer, Radiation: Radiative exchange among black and greyand spectral surfaces, Shape factors. Applications to cavities and enclosures. Integral equations approach. Radiation from gases, vapours and flames.
ME641A	CONDUCTION AND RADIATION	3-0-0-0-9	Lec 1: Conduction: Derivation of Heat Conduction Equation for Heterogeneous, Isotropic Materials in Cartesian Coordinates. Heat conduction equation for homogeneous, isotropic materials in Cartesian, Cylindrical and Spherical Coordinates. Summary of basic steady 1D heat conduction solutions including concept of resistances. Lec 2: Heat transfer from a fin of uniform crosssection. Fin efficiency and fin effectiveness. Fin with variable crosssection. Lec 3: Twodimensional Steady State Heat Conduction: Illustration 1: A rod with rectangular crosssection with three sides having temperature, To and other side at T f(x). Solution by Method of Separation of Variables. Isotherms and Heat Flux Lines. Lec 4: Illustration 2: 2D Steady State Heat Conduction with Constant Heat Generation in a Long Rod of Rectangular Crosssection with Boundaries at the ambient temperature (large heat transfer coefficient) methods for onedimensional media: The optically thin and optically thick

			approximations. Radiation in participating media: Gas radiation. Combined Conduction and Radiation: Example of a spacecraft radiator. Solar radiation. Greenhouse effect.
ME642	CONVECTIVE HEAT AND MASS TRANSFER	3-0-0--4	Introduction: Convective heat transfer and its applications; Forced, free and mixed convection; internal and external flow; heat transfer coefficient and its physical significance; dimensional analysis in convective heat transfer. Conservation Equations and boundary conditions: Mass, momentum, energy equations. External Laminar Forced Convection: Boundary layer equations; energy equation for flow over flat plate; similarity solution for flow over a flat plate having various boundary conditions and Prandtl numbers; Scale analysis; Approximate method; Viscous dissipation effect of laminar boundary layer. Internal Laminar Forced Convection: Developing and developed flow and heat transfer in a duct and circular pipe having various boundary conditions. Natural/Free and Mixed Convection: Boussinesq approximations; Similarity solution for flow over a flat plate; Scale analysis; Approximate method; Mixed convection and the corresponding governing equations. **Course Reference**:1. Introduction to Convective Heat Transfer Analysis by Patrick H. Oosthuizen and DavidLaylor (McGrawHill) Convective Heat and Mass Transfer by Kays, Crawford and Weigand (4th Edition, McGrawHill) Convective Heat Transfer by L. C. Burmeister (John Wiley and Sons); 2. Convective Heat Transfer by M FavreMarinet and S Tardu (John Wiley and Sons); 3.Principles of Convective Heat Transfer by Massoud Kaviany (2nd Edition, Springer); 4.Convective Heat Transfer by I. Pop and D. B. Ingham (Pergamon); 5.Convective Heat Transfer by Adrian Bejan (John Wiley and Sons); 6.Heat Convection by Latif M Jiji (Springer); 7.Viscous Fluid Flow by Frank M White (McGrawHill) Boundary Layer Theory by H Sctllichting (McGrawHill).
ME642A	CONVECTIVE HEAT AND MASS TRANSFER	3-0-0-0-9	Introduction: Convective heat transfer and its applications; Forced, free and mixed convection; internal and external flow; heat transfer coefficient and its physical significance; dimensional analysis in convective heat transfer. Conservation Equations and boundary conditions: Mass, momentum, energy equations. External Laminar Forced Convection: Boundary layer equations; energy equation for flow over flat plate; similarity solution for flow over a flat plate having various boundary conditions and Prandtl numbers; Scale analysis; Approximate method; Viscous dissipation effect oflaminar boundary layer. Internal Laminar Forced Convection: Developing and developed flow and heat transfer in a duct and circular pipe having various boundary conditions. Natural/Free and Mixed Convection: Boussinesq approximations; Similarity solution for flow over a flat plate; Scale analysis; Approximate method; Mixed convection and the corresponding governing equations. **Course Reference**: 1. Introduction to Convective Heat Transfer Analysis by Patrick H. Oosthuizen and DavidLaylor (McGrawHill); 2.Convective Heat and Mass Transfer by Kays,

			Crawford and Weigand (4th Edition,McGrawHill); 3.Convective Heat Transfer by L. C. Burmeister (John Wiley and Sons); Suggested reference books:Convective Heat Transfer by M FavreMarinet and S Tardu (John Wiley and Sons); 4.Principles of Convective Heat Transfer by Massoud Kaviany (2nd Edition, Springer)Convective Heat Transfer by I. Pop and D. B. Ingham (Pergamon); 5.Convective Heat Transfer by Adrian Bejan (John Wiley and Sons)Heat Convection by Latif M Jiji (Springer); 6.Viscous Fluid Flow by Frank M White (McGrawHill); 7.Boundary Layer Theory by H Sctllichting (McGrawHill)
ME643	COMBUSTION AND ENVIROMNENT	3-0-0-0-4	Flame phenomena in premixed combustible gases. Diffusion flames analysis of single fuel droplet, chemical reactions. Burning in convective atmosphere, spray combustion, fire modelling, radiation in flames, formation and control of pollution, Combustion chambers.
ME643A	COMBUSTION	3-0-0-0-9	Flame phenomena in premixed combustible gases. Diffusion flames analysis of single fuel droplet, chemical reactions. Burning in convective atmosphere, spray combustion, fire modelling, radiation in flames, formation and control of pollution, Combustion chambers.
ME647	INTRODUCTION TO TURBULENT FLUID MECHANICS	3-0-0-0-4	Measure of turbulence, diffusivity, length scales. Reynolds equation. Mixing length models. Homogeneous, isotropic turbulence, correlation and energy spectrum functions, integral micro scales. Grid turbulence, jets, wakes andmixing layers, boundary layers, logarithmic law near walls.
ME647A	INTRODUCTION TO TURBULENT FLOW	3-0-0-0-9	Measure of turbulence, diffusivity, length scales. Reynolds equation. Mixing length models. Homogeneous, isotropic turbulence, correlation and energy spectrum functions, integral micro scales. Grid turbulence, jets, wakes and mixing layers, boundary layers, logarithmic law near walls.
ME648	COMPUTER AIDED DESIGN OF THERMAL SYSTEMS	3-0-0--4	Simulation of thermal processes, application to casting, extrusion, heat treatment, thermal design of heat exchangers, electronic circuitry. Optimization search method and geometric programming, control strategy, data storage and retrieval. Expert systems.
ME649	EXPERIMENTAL METHODS IN THERMAL SCIENCES	3-0-0--4	Probes and transducers; Calibration; Turbulence measurement via statistical measures; Single and multipoint correlations; Signal conditioning; Optical methods, Interferometry, Schlieren, shadow graph, LCT, Laser Doppler velocimeter; Transient and frequency response. Computer aided data acquisition, tomography.
ME649A	EXPERIMENTAL METHODS IN THERMAL SCIENCES	3-0-0-0-9	Probes and transducers; Calibration; Turbulence measurement via statistical measures; Single and multipoint correlations; Signal conditioning; Optical methods, Interferometry, Schlieren, shadow graph, LCT, Laser Doppler velocimeter; Transient and frequency response. Computer aided data acquisition, tomography.
ME652	PRINCIPLES OF DYNAMICS	3-0-0--4	Review of kinematics and kinetics of a particle and a rigid body in plane motion. Euler's equations; Methods of analytical dynamics, Lagranges equations; Hamiltons principle; Dynamics in phase space and introduction to stability theory;

			Applications to engineering problems.
ME654	MECHANICS OF GROUND VEHICLES	3-0-0--4	Simple dynamical models of ground vehicles, mechanics of pneumatic tires, mechanics of vehicles terrain interaction, performance characteristics of roadvehicles, Handling characteristics. Directional stability, wheel shimmy, vehicle ride characteristics.
ME658	NUMERICAL CONTROL OF MACHINE TOOLS	3-0-0--4	Basic principle of numerical control, Classification of NC systems. NC part programming manual and computer aided. Drives, feedback devices, counting devices used in NC system. Interpolators for Manufacturing system. Control loopsfor NC system, Adaptive control, Industrial robots.
ME661	MACHINING SCIENCE I	3-0-0--4	Mechanics of chip formation, chip curl. Bluntness and cutting forces. Thermal aspects of machining. Tool wear, tool life and economics of machining. Mechanics of grinding, forces and specific energy, temperature. wheel wear and surface finish.
ME661A	MACHINING SCIENCE I	3-0-0-0-9	1. Introduction : Machining; Plastic Deformation, Tensile Test, Stress and Strain; Mechanism of Plastic Deformation: Slips, defects, plastic deformation on atomic scale; 2. Machining Process : Types of machining processes; Chip formation; Orthogonal and Oblique Cutting; Types of Chips; Builtup edge formation; 3. Tool Geometry : Reference planes; Tool specification: American System (ASA), continental or Orthogonal System (ORS), International or Normal Rake system (NRS); Tool angle relationships in ORS, ASA and NRS; Selection of Tool Angles; Multiplepoint cutting tools: twist drill, helical milling cutter; 4 . Mechanics of Metal Cutting : Merchant’s Circle Diagram; Coefficient of Friction: Determination of stress, strain and strain rate; Measurement of shear angle; Thin Zone model: Lee and Shaffer’s Relationship; Thick Zone model: Okushima and Hitomi Analysis; 5. Friction in Metal Cutting : Nature of sliding friction; Friction in Metal Cutting: Sticking and Sliding Zones, Analysis of Stress Distribution on the tool face: Zorevs model; Determination of mean angle of friction; 6. Mechanism of Oblique cutting : Rake angles in oblique cutting: Analytical determination of Normal Rake angle, velocity rake angle and effective rake angle; their relationship; shear angles in oblique cutting; velocity relationship; Force relationships in oblique cutting. **Course Reference**: 1. E.J.A. Armarego and R.H.BrownThe machining of Metals; 2. G Boothroyd Fundamentals of Metal Machining and Machine tools; 3. A.Ghosh and Asok Mallik Machining Science; 4. G.K.Lal and S.K.Choudhury Fundamental of Manufacturing Processes; 5. M.C.ShawMetal Cuttting Principles Journals:1. Trans. of ASME: Journal of Manufacturing Science and Engineering; 2. International Journal of Machine Tools and Manufacturing; 3. Annals of CIRP; 4. Journal of Materials processing technology; 5. Precision Engineering; 6. International Journal of Mechanical Sciences; 7. Proceedings, International Machine Tool Design and Research Conference.
ME662	MACHINING SCIENCE II	3-0-0--4	General classification of unconventional machining, chemical machining, electric discharge machining, Abrasive Jet and Ultrasonic Machining, electron beam machining, laser beam

			machining, ion beam machining, plasma arc machining; Comparative evaluation of different processes; Conventional machining with modifications.
ME662A	MACHINING SCIENCE II	3-0-0-0-9	I. Introduction to Advanced Manufacturing Processes. Introduction to manufacturing processes. Overview of nonconventional machining processes with (AJM, USM, ECM, EDM, EBM, LBM, AFM, MRF, MAF, MFP and MRAFF etc.) Introduction to use of nonconventional processes for micromachining. II. Mechanical Material Removal Processes (AJM, USM and WAJM) Abrasive Jet Machining (AJM): Introduction to abrasive jet machining (AJM), Mechanics of AJM, AJM process parameters Components of AJM (Abrasive, Gas, Setup), Mixing and Mass ratio and Material removal rate, Numerical approach to AJM, Modelling of Material Removal Rate (MRR). Ultrasonic Machining (USM): Basics of USM processes, Mechanics of USM, Process parameters of USM, Shaws model of USM mechanics, Compressed grain modelling and direct throw modelling and comparison, Dependence of process parameters in estimation of MRR, Numerical approach to USM, Ultrasonic machining setup, Design of acoustic ultrasonic head and feed mechanism in USM. Water Abrasive jet machining (WAJM): Introduction to WAJM (Basic principle and MRR estimation), WAJM process video. III. Nanofinishing processes. Introduction to nanofinishing and need of nanofinishing, Abrasive Flow Finishing (AFF), Introduction to AFF and self deformable feature, AFF machine elements, Magnetic Abrasive Finishing (MAF), Introduction to MAF, Elements of MAF, Setup and process parameters for AFF and MAF, Parametric analysis and applications of MAF and AFF. **Course Reference**: 1. Advanced manufacturing processes, Hassan Abdel, Gabad El Hoffy, McGraw Hill; 2. V.K. Jain, Advance Machining Processes, Allied Publisher Bombay; 3. Ghosh and Mallik, Manufacturing Science, EWP Private Ltd. Pandey P.C., Shan H.S., Modern machining processes, Tata McGrawHill Education; 4. Weller E.J., Nontraditional machining processes, Society of Manufacturing Engineers, Publications. The Science and Engineering of Microfabrication, Stephen P. Campbell, Oxford university press.
ME663	METAL FORMING	3-0-0--4	Fundmentals of plasticity, yield and flow, anisotropy, instability, limit analysis, descipline field theory. Applications to forging, wire and tube drawing, deep drawing, extrusion and rolling. High velocity forming.
ME663A	METAL FORMING	3-0-0-0-9	(I) Introduction. 1. Introduction to the course: different metal forming processes, importance of plasticity in the course. (II) Fundamentals of Plasticity. 1. Review Analysis of stress: transformation relations, principal stresses and directions, maximum normal and shear stresses, invariants, hydrostatic and deviatoric parts; Analysis of (infinitesimal) strain: transformation relations, principal strains, invariants, hydrostatic and deviatoric parts; (Infinitesimal) rotation, Stressstrain relations for isotropic, linearly elastic material. 2. Experimental observations on plasticity: yielding, strainhardening, viscoplasticity, temperature softening,

			Baushinger effect, hysteresis, incompressibility of plastic deformation, anisotropy, plastic instability; 3. Yield criterion for isotropic materials: von Mises and Tresca yield criterion, their geometric interpretation, convexity of the yield surfaces, experimental validation; 4. Incremental and rate forms of the measures of plastic deformation: linear incremental strain tensor, strain rate (i.e. the rate of deformation) tensor and their relation, incremental rotation tensor and spin tensor; 5. Change in yield criteria due to isotropic hardening: strain hardening and work hardening hypotheses, experimental validation of the hypotheses; 6. Plastic stressstrain relations for isotropic materials: plastic potential and associated flow rule, incremental and rate forms of elastoplastic stressstrain relations, simplifications for nonhardening and rigidplastic materials (Prandtl Reuss and LevyMises relations), Objective measures of stress rate and incremental stress; 7. Incremental and flow formulations of plasticity: updated Lagrangian and Eulerian formulations, boundary and initial conditions, examples. **Course Reference**: 1. The Mathematical Theory of Plasticity by R. Hill, Oxford University Press, 1950; 2. Engineering Plasticity by W. Johnson and P.B. Mellor, von Nostrand Co. Ltd,1972; 3. Theory of Plasticity by J. Chakrabarty, McGrawHill Book Co., InternationalEdition, 1987; 4. Metal Forming: Processes and Analysis by B. Avitzur, McGrawHill Book Co.,1968; 5. Continuum Theory of Plasticity by A.S. Khan and S. Huang, John Wiley and Sons Inc., 1995.
ME664	FUNDAMENTALS OF CASTING & SOLIDIFICATION	3-0-0-0-4	1 Introduction to Casting Problem: Principles of solidification, introduction to fluid flow and microstructure in a casting process; 2 Solidification Transnort Phenomena in Casting: Solidification of pure metals and alloys; Nucleation and growth; Natwe of solicVliquid interface; Constitutional undercooling; Dendritic growth; Directional solidification. Mathematical treatment of soliditication transport phenomena involved in a casting process (mass and heat transfer, fluid dynamics, mushy zone); Mathematical analysis ofre distribution of solute during solidification, micro and macrosegregation. Defects: Casting defects (compositional, microstructural, mold filling, shrinkage and other flow and heat transfer related defects), their causes and remedies; Understanding the role of transport phenomena in the formation of these defects.4 Case Studies of Some Selected Casting Processes: Mold, die and investment casting; Direct chill casting; Ingot casting; Directional solidification, Micro casting. Manipulation and control of casting structure, properties and defects through advanced casting processes Inoculation practices, rheocasting, thixocasting, multiphysics casting processes involving magnetic fields. 5 Casting Design bv Controlling the Accomnanied Heat Transfer to Fluid Flow and Solidification: Mathematical treatment of solidification rates exact and approximate methods; mold casting heat transfer. Riser design, feeding distance, mold filling and their relation with temperature distribution and dimensional design of the casting. **Course Reference**: 1. Science and Engineering of Casting

			Solidification, Doru M Stefanescu, 2nd ed; 2. Solidification ProcessJng, M C Fleming, McGraw Hill; 3. Principles of metal casting, R W Heine, C R Loper and Rosenthal, Tata McGraw Hill, New Delhi; 4. Casting, J Campbell, Butterworth Heinemann; 5. Manufacturing Engineering and Technology, S Kalpakjian; 6. Fundamentals of Modern Manufacturing, M P Groover; 7. Fundamentals of Manufacturing Processes, G K Lal and S K Choudhury; 8. Metals Handbook Metal Casting, ASM.
ME664A	FUNDAMENTALS OF CASTING & SOLIDIFICATION	3-0-0-0-9	1 Introduction to Casting Problem: Principles of solidification, introduction to fluid flow and micrstntcture in a casting process; 2 Solidification Transnort Phenomena in Casting: Solidification of pure metals and alloys; Nucleation and growth; Natwe of solid Vs Iiquid interface; Constitutional undercooling; Dendritic growth; Directional solidification.Mathematical treatment of soliditication transport phenomena involved in a casting process (mass and heat transfer, fluid dynamics, mushy zone); Mathematical analysis of distribution of solute during solidification, micro and macrosegregation.Defects: Casting defects (compositional, microstructural, mold filling, shrinkage and other flow and heat transfer related defects), their causes and remedies; Understanding the role of transport phenomena in the formation of these defects; 4 Case Studies of Some Selected Casting Processes: Mold, die and investment casting; Direct chill casting; Ingot casting; Directional solidification, Micro casting.Manipulation and control of casting structure, properties and defects through advanced casting processes Inoculation practices, rheocasting, thixocasting, multiphysics casting processes involving magnetic fields; 5 Casting Design bv Controlling the Accompanied Heat Transfer to Fluid Flow and Solidification: Mathematical treatment of solidification rates exact and approximate methods;mold casting heat transfer.Riser design, feeding distance, mold filling and their relation with temperature distribution and dimensional design of the casting. **Course Reference**: 1. Science and Engineering of Casting Solidification, Doru M Stefanescu, 2nd ed; 2. Solidification ProcessJng, M C Fleming, McGraw Hill; 3. Principles of metal casting, R W Heine, C R Loper and Rosenthal, Tata McGraw Hill, New Delhi; 4. Casting, J Campbell, Butter worth Heinemann; 5. Manufacturing Engineering and Technology, S Kalpakjian; 6. Fundamentals of Modern Manufacturing, M P Groover; 7. Fundamentals of Manufacturing Processes, G K Lal and S K Choudhury; 8. Metals Handbook Metal Casting, ASM.
ME665	MICROMACHINING	3-0-0-0-4	1. Introduction to the Course & Classification of MMPs, Part1: Mechanical Type Advanced Micromachining Processes, 2. Abrasive Jet Micro Machining (AJMM), 3. Ultrasonic Micro Machining (USMM), 4. Abrasive Water Jet Micro Machining (AWJMM), Part2: Abrasive Based Nano Finishing Processes, 5. Abrasive Flow Finishing (AFF), 6. Chemo mechanical Polishing (CMP), 7. Magnetic Abrasive Finishing (MAF), 8. Magnetorheological Finishing (MRF), 9. Magnetorheological Abrasive Flow Finishing (MRAFF), 10. Magnetic Float

			Polishing (MFP), 11. Elastic Emission Machining, Part3: Thermoelectric Type Micro Machining Processes, 12. Electric Discharge Micro Machining (EDMM), 13. Wire EDM, EDDG, ELID, 14. Laser Beam Micro Machining (LBMM), 15. Electron Beam Micro Machining (EBMM),16. Ion Beam Machining **Course Reference**: 1. Introduction to Micromachining, V. K. Jain (Ed.), Narosa publisher, 2010; 2. Micromachining, J. A. McGeough,3. Micromanufacturing, V. K. Jain (Ed.), CRC press, 2012; 4. Micromanufacturing & Nanotechnology, N. P. Mahalik, Springer; 5. Microfacbrication & Nanomanufacturing, Mark J. Jackson, CRC press.
ME665A	MICROMACHINING	3-0-0-0-9	1. Introduction to the Course & Classification of MMPs, Part 1: Mechanical Type Advanced Micromachining Processes, 2. Abrasive Jet Micro Machining (AJMM), 3. Ultrasonic Micro Machining (USMM), 4. Abrasive Water Jet Micro Machining (AWJMM), Part 2: Abrasive Based Nano Finishing Processes, 5. Abrasive Flow Finishing (AFF), 6. Chemo mechanical Polishing (CMP), 7. Magnetic Abrasive Finishing (MAF), 8. Magnetorheological Finishing (MRF), 9. Magnetorheological Abrasive Flow Finishing (MRAFF), 10. Magnetic Float Polishing (MFP), 11. Elastic Emission Machining, Part3: Thermoelectric Type Micro Machining Processes, 12. Electric Discharge Micro Machining (EDMM), 13. Wire EDM, EDDG, ELID, 14. Laser Beam Micro Machining (LBMM), 15. Electron Beam Micro Machining (EBMM),16. Ion Beam Machining **Course Reference**: 1.Introduction to Micromachining, V. K. Jain (Ed.), Narosa publisher, 2010; 2. Micromachining, J. A. McGeough; 3. Micromanufacturing, V. K. Jain (Ed.), CRC press, 2012; 4. Micromanufacturing & Nanotechnology, N. P. Mahalik, Springer; 5. Microfacbrication & Nanomanufacturing, Mark J. Jackson, CRC press.
ME667	ADHESION, FRICTION AND LUBRICATION FOR MICROMACHINES	3-0-0-0-4	I. History of friction and lubrication studies, Origins of friction, Coulomb's theory, Archard's theory, Bowden and Tabor's theory, Hardness of metals and ductile materials, contact area calculations, Hertzian model, JKR model, Atomic scale understanding of friction, Surface forces (van der Waals, electrostatic, hydrogen bonding etc.), adhesion models/nanorheology, meniscus and surfce models, static friction, stickslip phenomenon, friction anisotropy, concept ofsuperlubricity, micronanoscale wear phenomenon, tribology in wet environment, capillary force, Young and Laplace equation (9 lectures); 2. Liquid lubrication, lubrication regimes, load bearing equation, journal bearings, elastohydro dynamic lubrication, film thickness calculation, Boundary lubrication, characteristics of boundary lubricants, liquid lubricants, additives, confined molecularly thin liquid films, Friction phase diagram, nanolubrication and effects of nanotexturing on nanolubrication. (91ectures); 3. Nanotribological measurements: nanoscratching, atomic force microscopy tests, friction force microscopy, surface force apparatus, Tabor and Winterton design for surface force measurement, surface analytical tools such as FTIR, XPS and FESEM fortribological research. Experimental results on model surfaces. (9 lectures); 4. Effects of surface/material parameters on micro/nanoscale

			friction (Load effects, speed effects, surface energy, surface l roughness effects on adhesion and friction, humidity molecular structure, contact mechanical properties, hardness). Scaling effect, ribocharging (6 lectures) Tribology on the Small Scale: A Bottom Up Approach to Friction, Lubrication, and Wear. **Course Reference**: 1. C. Mathew Mates, Oxford University Press, 2007 Nanotribology and Materials in MEMS, Sujeet K. Sinha, N. Satyanarayana and Seh Chun Lim (eds.), (ISBN 9783642369346) Springer Berlin, 2013; 2. Polymer Tribology by Sujeet K. Sinha and Brian J. Briscoe (editors) (Imperial College Press); 3. Biological Micro and Nanotribology: Nature's Solutions by M. Scherge, S. N. Gorb, Springer Verlag
ME667A	ADHESION, FRICTION AND LUBRICATION FOR MICROMACHINES	3-0-0-0-9	I. History of friction and lubrication studies, Origins of friction, Coulomb's theory, Archard's theory, Bowden and Tabor's theory, Hardness of metals and ductile materials, contact area calculations, Hertzian model, JKR model, Atomic scale understanding offriction, Surface forces (van der Waals, electrostatic, hydrogen bonding etc.), adhesion models/nanorheology, meniscus and surfce models, static friction, stickslip phenomenon, friction anisotropy, concept of superlubricity, micronanoscale wear phenomenon, tribology in wet environment, capillary force, Young and Laplace equation (9 lectures) 2. Liquid lubrication, lubrication regimes, load bearing equation, journal bearings, elasto hydrodynamic lubrication, film thickness calculation, Boundary lubrication, characteristics of boundary lubricants, liquid lubricants, additives, confined molecularly thin liquid films, Friction phase diagram, nanolubrication and effects ofnano texturing on nanolubrication. (91ectures) 3. Nanotribological measurements: nanoscratching, atomic force microscopy tests, friction force microscopy, surface force apparatus, Tabor and Winterton design for surface force measurement, surface analytical tools such as FTIR, XPS and FESEM for tribological research. Experimental results on model surfaces. (9 lectures) 4. Effects of surface/material parameters on micro/nanoscale friction (Load effects, speed effects, surface energy, surface l roughness effects on adhesion and friction, humidity molecular structure, contact mechanical properties, hardness). Scaling effect, ribocharging (6 lectures) Tribology on the Small Scale: A Bottom Up Approach to Friction, Lubrication, and Wear. **Course Reference**: 1. C. Mathew Mates, Oxford University Press, 2007 Nanotribology and Materials in MEMS, Sujeet K. Sinha, N. Satyanarayana and Seh Chun Lim (eds.), (ISBN 9783642369346) Springer Berlin,2013; 2. Polymer Tribology by Sujeet K. Sinha and Brian J. Briscoe (editors) (Imperial College Press) Biological Micro and Nanotribology: Nature's Solutions by M. Scherge, S. N. Gorb, Springer Verlag
ME669A	MODELING THERMAL TRANSPORT IN MANUFACTURING PROCESSES	3-0-0-0-9	1. Review of fundamentals of thermal transport in manufacturing: 1. Introduction to the course Importance of heat transfer in manufacturing and applications. 2. Steady and transient heat conduction, Convection and Radiation, Natural convection. 3. Fluid flow and Mass transfer. 2. Finite Difference and Finite Volume based modeling of heat transfer in manufacturing and numerical implementation: 1. Basic

			introduction to FDM and FVM techniques, Mathematical formulation of thermal transport, Governing equations and general scalar transport equation, 2. Steady and unsteady problems, Initial and Boundary conditions, Convectiondiffusion problems, 3. Mesh terminology, Accuracy, Consistency, Stability and Convergence, 4. Phase change Enthalpy based algorithm for Melting/solidification, Twophase mushy zone flows, Liquidvapour phase change involved in manufacturing, 5. Illustration using code. 3. Case studies on modeling of thermal transport in manufacturing processes: 1. Solidification processing Modeling of moving melting/solidification phase change interface, Alloy solidification, Segregation, Two-phase mushy zone flow, Modeling of casting, Marangoni convection driven flow, Modeling of welding, 2. Heat assisted manufacturing process Thermal modeling using enthalpy method for solid liquid and/ or liquidvapour phase change interface. Melt pool formation and flow behaviour, Beam heat flux models, Eample problems of thermal modeling in Laser Melting (LM), Electron Beam Melting (EBM), Machining: Electric Discharge Machining (EDM) and Heat assisted micro manufacturing process, 3. Thermal deposition process Modeling of free surface evolution, Modeling of droplet impact and deposition on substrates. **Course Reference**: 1. R.N. Smith, C.H. Doumanidis, R. Pitchumani, Chapter 17, Heat Transfer in Manufacturing and Materials Processing, John Wiley & Sons Inc., 2006; 2. T.L. Bergman, A.S. Lavine, F.P. Incropera, D.P. DeWitt, Fundamentals of Heat and Mass Transfer, 6th Edition, Wiley India Pvt. Ltd., 2006; 3. S.V PLatankar, Numerical Heat Transfer and Fluid Flow, McGraw Hill, New York, 1980; 4. J. Dowden (Ed.), The Theory of Laser Materials Processing in Heat and Mass Transfer in Modern Technology, Springer, 2008; 5. D.M. Stefanescu Science and Engineering of Casting Solidification, 2nd ed., Springer, 2008; 6. M.P. Groover, Fundamentals of Modern Manufacturing, John Viley & Sons Inc., 2010; 7. Larry F. Jeffus, Welding: Principles and Applications, 4th ed., Thomson Learning, 1999; 8. L. Pawlowski, The Science and Engineering of Thermal Spray Coatings, 2nd ed., John Wiley & Sons Inc, 2008. 24-MAR-15
ME670A	ADDITIVE MANUFACTURING	3-0-0-0-9	1. Introduction to Additive Manufacturing AM): General overview, Introduction to reverse engineering, Traditional manufacturing v/s AM, Computer aided design (CAD) and AM. Different AM processes and relevant process physics AM process chain, Application level: Direct processes Rapid Prototyping, Rapid Tooling, Rapid Manufacturing; Indirect Processes Indirect Prototyping, Indirect Tooling, Indirect Manufacturing. 2. Materials science for AM: Discussion on different materials used for AM. Use of multiple materials, maltifunctional and graded materials in AM. Role of solidification rate. Evolution of nonequilibrium structure. Structure property relationship. Grain structure and microstructure. 3. AM technologies: Powder based AM processes involving sintering and melting (selective laser sintering, laser engineered net shaping, electron beam melting,

			high energy beam involvement). Printing processes (droplet-based 3D printing) Solidbased AM processes extrusion based fused deposition modeling (FDM), Laminated object manufacturing (LOM) Stereo lithography. Microand nanoadditive manufacturing process. 4. Mathematical models for AM: Transport phenomena models: temperature, fluid flow and composition, buoyancy driven flow, surface tension driven free surface flow (study of molten pool). Case studies: Numerical Modeling of fusion based AM process, Powder bed melting based process, Droplet based printing process. Residual stress, part fabrication time, part fabrication cost, optimal orientation and optimal layer thickness. Defect in AM and role of transport phenomena on its formation. Simulations (choice of parameter, experimental data and comparison between simulation and experiments) Model validation for different aspects. **Course Reference**: 1. Ian Gibson, David W. Rosen, Brent Stucker, Additive manufacturing technologies: rapid prototyping to direct digital manufacturing, Springer, 2010; 2. Andreas Gebhardt, Undeerstanding additive manufacturing: rapid prototyping, rapid tooling, rapid manufacturing, Hanser Publishers, 2011; 3. J.D. Majumdar and I. Manna, Laserassisted fabrication of materials, Springer Series in Material Science, eISBN: 9783642283598; 4. L. Lu, J. Fuh and Y. S. Wong, Laserinduced materials and processes for rapid prototyping, Kluwer Academic Press, 200; 5. Zhiqiang Fan and Frank Liou, Numerical modeling of the additive manufacturing (AM) processes of titatium alloy, InTech, 2012; 6. C.K. Chua, K.F. Leong and C.S. Lim, Rapid prototyping: principles and applications/ 3rd Edition, World Scientific, 2010. 24-MAR-15
ME671	EXPERIMENTAL STRESS ANALYSIS	3-0-0--4	Strain Gauge, strain rosettes and transducer applications. Photoelasticity, materials and their selection. Introduction to 3D photoelasticity. Brittle coating methods, Moire method of strain analysis and nondestructive testing using xraysand ultrasonic devices.
ME673	FLOW, HEAT & MASS TRANSFER THROUGH POROUS MEDIA	3-0-0-0-4	I. Fundamentals: REV, Mass, momentum and energy transport, Darcy and NonDarcy equations equilibrium and nonequilibrium conditions, species transport, radioactive decay. 2. Effective medium approximation: equivalent thermal conductivity, viscosity, dispersion; 3. Exact solutions: Flow over a flat plate, flow past a cylinder, boundary layers, reservoir problems.; 4. Special topics: Field scale and stochastic modeling, Turbulent flow, compressible flow, multiphase flow, numerical techniques, hierarchical porous media, multiscale modelling; 5. Engineering applications: Groundwater, waste disposal, oil and gas recovery, regenerators, energy storage systems. 6. Experimental techniques: Flow visualization, quantitative methods, inverse parameter estimation. **Course Reference** : 1. Principles of Heat Transfer in Porous Media, by M. Kaviany, Springer New York(1995); 2. Transport Phenomena in Porous Media, Volumes 1111, edited by D. R. Ingham and LPop, Elsevier, New York (19982005); 3. Dynamics of Fluids in Porous Media, J. Bear, Dover (1988); 4.

			Introduction to Modeling of Transport Phenomena in Porous Media, J. Bear and Y.Bachmat, Kluwer Academic Publishers, London (1990); 5. Enhanced Oil Recovery, L.W. Lake, Gulf Publishing Co. Texas (1989); 6. The Mathematics of Reservoir Simulation, R.E. Ewing, SIAM Philadelphia (1983).
ME681	MATHEMATICS FOR ENGINEERS	3-0-0--4	Introduction. 1. Introduction to the course. (II) Linear Algebra. 1.Vector spaces: definition, linear independence of vectors, basis, inner product and inner product space, orthogonality, GramSchmidt procedure, subspaces. 2. Matrices: coordinate dependent linear transformations, null and range spaces. 3. Linear algebraic equations: existence and uniqueness of solution, elementary row/column operations, Gauss elimination and Gauss Jordon methods, Echelon form, pivoting, LU decomposition and Cholesky method, GaussSeidel and Jacobi iterative methods, condition number, minimum norm and least square error solutions. 4. Eigenvalues and eigenvectors of matrices: properties like multiplicity, eigenspace, spectrum and linear independence of eigenvectors, similarity transformation and Jordon canonical form, eigenvalues/eigenvectors of symmetric matrices: orthogonal diagonalization. 5. Iterative methods to find eigenvalues/ eigenvectors of symmetric matrices: forward iteration and Mises power method, inverse iteration. (III) Tensor Algebra. 1. Index Notation and Summation Convention. 2.Tensor algebra: tensor as a linear vector transformation, dyadic representation, transformation of components, product of tensors, transpose, decomposition into symmetric and antisymmetric parts, invariants, decomposition into isotropic and deviatoric parts, inner product and norm, inverse, orthogonal tensors, eigenvalues and eigenvectors, squareroot, positive definite symmetric tensor, polar decomposition, tensors of higher order. **Course Reference**: 1. Advanced Engineering Mathematics by E. Kreyszig, John Wiley and Sons, International 8th Revised Edition, 1999; 2. Applied Mathematical Methods by B. Dasgupta, Pearson Education, 2006.
ME681A	MATHEMATICS FOR ENGINEERS	3-0-0-0-9	Introduction. 1. Introduction to the course. (II) Linear Algebra; 1. Vector spaces: definition, linear independence of vectors, basis, inner product and inner product space, orthogonality, GramSchmidt procedure, subspaces. 2. Matrices: coordinate dependent linear transformations, null and range spaces. 3. Linear algebraic equations: existence and uniqueness of solution, elementary row/column operations, Gauss elimination and Gauss Jordon methods, Echelon form, pivoting, LU decomposition and Cholesky method, GaussSeidel and Jacobi iterative methods, condition number, minimum norm and least square error solutions. 4. Eigenvalues and eigen vectors of matrices: properties like multiplicity, eigen space, spectrum and linear independence of eigen vectors, similarity transformation and Jordon canonical form, eigenvalues/eigenvectors of symmetric matrices: orthogonal diagonalization. 5.Iterative methods to find eigenvalues/ eigenvectors of symmetric matrices: forward iteration and Mises power method, inverse iteration. (III) Tensor Algebra. 1. Index Notation and Summation Convention. 2.Tensor algebra:

			tensor as a linear vector transformation, dyadic representation, transformation of components, product of tensors, transpose, decomposition into symmetric and antisymmetric parts, invariants, decomposition into isotropic and deviatoric parts, inner product and norm, inverse, orthogonal tensors, eigenvalues and eigenvectors, squareroot, positive definite symmetric tensor, polar decomposition, tensors of higher order. **Course Reference**: 1. Advanced Engineering Mathematics by E. Kreyszig, John Wiley and Sons, International 8^{th} Revised Edition, 1999; 2. Applied Mathematical Methods by B. Dasgupta, Pearson Education, 2006.
ME682	DIFFERENCE EQUATIONS FOR ENGINEERS	3-0-0-0-4	1. Introduction and Some Applications of Difference Equations in Engineering (1 lecture) 2. Preliminaries in algebra and analysis (3 lectures) 3. Analogies between differential and difference equations (1 lecture) 4. Elementary Difference Operations. The Difference and shift operators (3 lectures) 5. The Difference Calculus. Summation (3 lectures)6. Interpolation, Extrapolation (1 lecture)7. Generating functions (2 lectures)8. Linear difference equations, First order equations (2 lectures)9. Higher Order Difference Equations (1 lecture)10. Linear difference equations with constant coefficients (2 lectures)11. Linear difference equations with variable coefficients (2 lectures)12. Method of undetermined coefficients and variation of parameters (2 lectures)13. Limiting behavior of solutions (1 lecture)14. Systems of Linear difference equations and application (1 lecture)15. The ztransform and its applications (2 lectures)16. The Sturmian theory and Fourier analysis (3 lectures)17. Nonlinear difference equations and boundary value problems (1 lecture)18. Asymptotic methods (1 lecture)19. Stability theory and relevance to dynamical systems (1 lecture)20. Partial Difference Equations (2 lectures)21. Lagrangian and Hamiltonian Formalism for Difference Equations. Symmetry (2 lectures)22. Difference Equations with Continuous Time, Differentialdifference equations (1 lecture)23. Discrete Mechanics (1 lecture)24. Open problems (1 lecture) **Course Reference**: 1. An Intoduction to Difference Equations, S. N. Elaydi (Springer) (textbook); 2. Difference Equation, W. G. Kelley and A. C. Peterson (Academic Press); 3. Finite Difference Equations. H. Levy and F. Lessman (MacMillan); 4. A treatise on the Calculus of Finite Differences. G. Boole. (MacMillan)
ME682A	DIFFERENCE EQUATIONS FOR ENGINEERS	3-0-0-0-9	1. Introduction and Some Applications of Difference Equations in Engineering (1 lecture); 2. Preliminaries in algebra and analysis (3 lectures); 3. Analogies between differential and difference equations (1 lecture); 4. Elementary Difference Operations. The Difference and shift operators (3 lectures); 5. The Difference Calculus. Summation (3 lectures); 6. Interpolation, Extrapolation (1 lecture); 7. Generating functions (2 lectures); 8. Linear difference equations, First order equations (2 lectures); 9. Higher Order Difference Equations (1 lecture); 10. Linear difference equations with constant coefficients (2 lectures); 11. Linear difference equations with

			variable coefficients (2 lectures); 12. Method of undetermined coefficients and variation of parameters (2 lectures); 13. Limiting behavior of solutions (1 lecture); 14. Systems of Linear difference equations and application (1 lecture)15. The ztransform and its applications (2 lectures)16. The Sturmian theory and Fourier analysis (3 lectures)17. Nonlinear difference equations and boundary value problems (1 lecture)18. Asymptotic methods (1 lecture)19. Stability theory and relevance to dynamical systems (1 lecture)20. Partial Difference Equations (2 lectures)21. Lagrangian and Hamiltonian Formalism for Difference Equations. Symmetry (2 lectures)22. Difference Equations with Continuous Time, Differentialdifference equations (1 lecture)23. Discrete Mechanics (1 lecture)24. Open problems (1 lecture) **Course Reference**: 1. An Intoduction to Difference Equations, S. N. Elaydi (Springer) (textbook); 2. Difference Equation, W. G. Kelley and A. C. Peterson (Academic Press); 3. Finite Difference Equations. H. Levy and F. Lessman (MacMillan);4. A treatise on the Calculus of Finite Differences. G. Boole. (MacMillan).
ME685	APPLIED NUMERICAL METHODS	3-0-0--4	MATLAB, Mathematical modeling, algorithms, Taylor series expansion, root finding, interpolation, extrapolation; Solution of linear algebraic systems, determinant, inverse: norms and condition number; Solution of nonlinear algebraic systems. Numerical integration. R. K. Method, Solution of ODE and linear PDEs by finite differences.
ME685A	APPLIED NUMERICAL METHODS	3-0-0-0-9	1. Concepts of Algorithms and Programming; Revision of computer languages such as MATLAB, Fortran, and C++; 2. Introduction to Mathematical Modelling; 3. Taylor and Fourier series expansion; 4. Root finding; 5. Interpolation, splines, extrapolation; 6. Regression and curve fitting; 7. Solution of simultaneous linear algebraic systems; nonlinear algebraic equations; 8. igenvalues and eigenvectors; 9. Solution of simultaneous nonlinear algebraic systems; 10. Numerical integration, Simpsons rule, Gaussian quadrature; 11. Solution of ODE: R. K. Methods; PredictorCorrector methods; boundaryvalue problems; 12. Systems of ODEs; convergence and error studies; 13. Linear PDEs by finite differences. Programming projects based on mathematical modelling followed by an application of the numerical methods given above. **Course Reference**: 1. Numerical Methods for Engineers; Steven C. Chapra and Raymond P. Canale, 7th; 2. Introduction to Numerical Analysis, S.S. Sastry; Prentice Hall of India, 2012. edition, McGrawHill, 2014; 3. Numerical Methods for Engineers, Santhosh.K. Gupta, New Age International; 2012; 4. Applied Numerical Methods for Digital Computation, M.L. James, G.M. Smith & J.C. Wolford, Harper Collins College Division; 4Th edition, 1993.
ME689	MICROSCALE THERMAL ENGINEERING	----4	MicroMechanical systems (MEMS), Micro Channels, Heat pipes, jets, valves,Heat Sinks, Solar cells, Bearings, Pumps, Heat pipes, Jets, valves, Heat sinks, Solar Cells, Bearings, Pumps, Flow Sensors and actuators, Fins, Drug delivery

			systems, Mass, Momentum, Heat and charge transport equations, Characteristic Nondimensional parameters, Microscale Heat conduction, Heat transport in thinfilms and at solidsolid interfaces, Convective diffusion phenomena, Enzyme substrate reactions, channel flow with soluble or rapidly reacting walls, solutions of electrolytes, Electric double layer, Electro kinetic phenomena, electro osmosis, Electroosmotic pumps, Surface tension driven flows, Coating flows,Thermocapillary flows, Molecular dynamics simulations.
ME689A	MICROSCALE THERMAL ENGINEERING	----9	MicroMechanical systems (MEMS), Micro Channels, Heat pipes, jets, valves,Heat Sinks, Solar cells, Bearings, Pumps, Heat pipes, Jets, valves, Heat sinks, Solar Cells, Bearings, Pumps, Flow Sensors and actuators, Fins, Drug delivery systems, Mass, Momentum, Heat and charge transport equations, Characteristic Nondimensional parameters, Microscale Heat conduction, Heat transport in thinfilms and at solidsolid interfaces, Convective diffusion phenomena, Enzyme substrate reactions, channel flow with soluble or rapidly reacting walls, solutions of electrolytes, Electric double layer, Electrokinetic phenomena, electro osmosis, Electroosmotic pumps, Surface tension driven flows, Coating flows, Thermocapillary flows, Molecular dynamics simulations.
ME690	ALTERNATIVE FUELS & ADVANCE IN IC ENGINES	3-0-0--4	Combustion and Fuels, Combustion process in SI and CI engines, Petroleum based liquid fuels and refining, Liquid alternative Fuels, Advantages, potential,problems associated with utilization, Vegetable oils, Biodiesel, Emulsified fuels,Effect on Lubricating oils, Gaseous Alternative Fuels, Hydrogen, Compressed Natural Gas, Liquified petroleum Gas, Dimethyl ether, Hythane, Multifuel engines, Modern developments in IC Engines, EGR, MPFI, GDI, HCCI, Turbo charged engines, Optical Measurement techniques, Fuel atomization and spray visualization techniques, Laser doppler Anemometry, Particle image velocimetry, 3D and Holographic PIV, optical engines, sources and Nature of various types of pollutants: Pollution monitoring instruments and techniques, Control measures, emission legislations.
ME690A	ALTERNATIVE FUELS & ADVANCE IN IC ENGINES	3-0-0-0-9	Combustion and Fuels, Combustion process in SI and CI engines, Petroleum based liquid fuels and refining, Liquid alternative Fuels, Advantages, potential,problems associated with utilization, Vegetable oils, Biodiesel, Emulsified fuels,Effect on Lubricating oils, Gaseous Alternative Fuels, Hydrogen, Compressed Natural Gas, Liquified petroleum Gas, Dimethyl ether, Hythane, Multifuelengines, Modern developments in IC Engines, EGR, MPFI, GDI, HCCI, Turbo charged engines, Optical Measurement techniques, Fuel atomization and spray visualization techniques, Laser doppler Anemometry, Particle image velocimetry, 3D and Holographic PIV, optical engines, sources and Nature of various types of pollutants: Pollution monitoring instruments and techniques, Control measures,emission legislations.
ME691	ENGINE MANAGEMENT	3-0-0--4	1. Introduction; 2. Diesel Engine management: cylinder charge control systems, basic principles of diesel fuel injection, mixture distribution, fuel injection parameters, various designs

			and overview of diesel fuel injection systems, fuel supply systems to the low pressure stage, governors and control systems for inline fuel injection pumps, distributor fuel injection pump systems, helix and port controlled distributor injection pumps, overview of discrete cylinder systems,single plunger fuel injection pumps, unit injector systems, and unit pump systems, common rail systems, injection nozzles, minimizing emissions inside the engine, electronic diesel control (EDC), electronic control unit (ECU). (25); 3. Gasoline Engine Management: cylinder charge control systems, fuels supply, manifold fuel injection, gasoline direct injection, operation of gasoline engine on natural gas, ignition system, inductive ignition systems, ignition coils, spark plugs, sensors: temperature sensors, engine speed sensors, hall effect phase sensors, hot film air mass sensors,piezoelectric knock sensor, micromechanical pressure sensor, high pressure sensor, two step lambda sensor,Electronic control unit, operating conditions, design and data processing. (15) **Course Reference**: 1. Internal Combustion engine fundamentals: J B Heywood, McGraw Hill Publications; 2. Gasoline Engine Management: Robert Bosch GMBH; 3. Diesel Engine Management: Robert Bosch GMBH; 4. The Internal combustion Engine in theory and practice: C F Taylor, MIT Press, Cambridge; 5. Internal Combustion Engines and Air Pollution: E FObert, Intext Educational Publishers, NY; 6. Advanced Engine Technology: Heinz Heisler ISBN 0340568224, SAE Publications.
ME691A	ENGINE MANAGEMENT	3-0-0-0-9	1. Introduction; 2. Diesel Engine management: cylinder charge control systems, basic principles of diesel fuel injection, mixture distribution, fuel injection parameters, various designs and overview of diesel fuel injection systems, fuel supply systems to the low pressure stage, governors and control systems for inline fuel injection pumps, distributor fuel injection pump systems, helix and port controlled distributor injection pumps, overview of discrete cylinder systems,single plunger fuel injection pumps, unit injector systems, and unit pump systems, common rail systems, injection nozzles, minimizing emissions inside the engine, electronic diesel control (EDC), electronic control unit (ECU). (25); 3. Gasoline Engine Management: cylinder charge control systems, fuels supply, manifold fuel injection, gasoline direct injection, operation of gasoline engine on natural gas, ignition system, inductive ignition systems, ignition coils, spark plugs, sensors: temperature sensors, engine speed sensors, hall effect phase sensors, hot film air mass sensors,piezoelectric knock sensor, micromechanical pressure sensor, high pressure sensor, twostep lambda sensor,Electronic control unit, operating conditions, design and data processing. (15) **Course Reference**: 1. Internal Combustion engine fundamentals: J B Heywood, McGraw Hill Publications; 2. Gasoline Engine Management: Robert Bosch GMBH; 3. Diesel Engine Management: Robert Bosch GMBH; 4. The Internal combustion Engine in theory and practice: C F Taylor, MIT Press, Cambridge; 5. Internal Combustion Engines and Air

			Pollution: E FObert, Intext Educational Publishers, NY; 6. Advanced Engine Technology: Heinz Heisler ISBN 0340568224, SAE Publications.
ME698A	ENERGY STORAGE SYSTEMS	3-0-0-0-9	Multiobjective optimization, Robust design techniques (variation reduction techniques), Optimal control, stochastic programming. Role of Optimization inCAD: Why optimization? Optimization Geometric modelling Analysis. Implementation Issues: computational time versus accuracy, Interfacing with geometric modelling and analysis softwares, Graphics interfacing, Choice of Hardware platform. Application to engineering design problems, comparison with existing solutions.
ME698C	FLUID MECHANICS OF FLAPPING WINGS		Condensed Syllabus: Flapping foils in nature, airfoil theory, vortex dynamics, governing equations and parameters, kinematics, vortex wakes, drag to thrust transition, thrust by forward moving foils, unsteady thin airfoil theory, unsteady actuator disk theory, efficiency estimates, scaling laws, thrust generation in quiescent ambient, deflected wakes, unsteady mechanisms, flexible flapping foils, fluid-flexible-structure interaction, 3D foils, foils in tandem, biomimetic applications. Lecture-wise Break-up: (total 40 Lectures) Introduction and Fundamentals: (8 Lectures); Flapping foils in nature; Why flapping foils?; Historical development; Vortex dynamics; Airfoil theory; Flapping foil terminologies; Fixed, Rotary Versus Flapping foilsThrust and Lift Generation by Flapping Foil: (15 Lectures); Self-propelling bodies; Governing equations and parameters; Kinematics; Vortex wakes; Drag-thrust transition; Unsteady thin foil theory; Force prediction for forward moving foils; Simplified aerodynamics models; Unsteady actuator disk theory; Scaling laws; Thrust, power and efficiency estimates; Parametric study; Thrust generation in quiescent ambient; Wake deflection. Unsteady Mechanisms: (6 Lectures); Unsteady mechanisms for thrust and lift enhancement; Dynamic stall; Leading edge vortices; Rapid pitch-up; Wake capture; Clap and Fling; Wagner effect. Flapping Flexible Foil: (8 Lectures) Flexible foils in natural world; Structural models; Scaling parameters; Flow-Flexible-Structure coupling; Chordwise and spanwise flexibility; Mechanisms of flow and force generation; Suppressing jet deflection; Optimal flexibility; Flexible Versus Rigid foils. Biomimetic Propulsion and Other Topics: (3 Lectures) Flapping foils as propulsive mechanism; Biomimetic applications in Micro Aerial Vehicles (MAVs) and Autonomous Underwater Vehicles (AUVs); Flapping foils for air & amp; aquatic vessels; 3-D foils; Foils in tandem; Experimental techniques; Simulations; Robotic fish, bird, insect models. **Course Reference** : 1. Theory of wing sections - I. H. Abbott (Dover, 1959); 2. Fluid Mechanics – F. M. White (Tata McGraw Hill, 2008); 3. Vortex dynamics; P. G. Saffman (Cambridge University Press, 1992; 4. Aerodynamic Theory – W. F. Durand (Julius Springer, 1935); 5. An introduction to flapping wing aerodynamics – W. Shyy, H. Aono, C. Kang, H. Liu (Cambridge Aerospace Series, 2013); 6. Aerodynamics of low Reynolds number flyers ; W.

			Shyy, Y. Lian, J. Tang, D. Viieru, H. Liu (Cambridge University Press, 2008)
ME698D	INVISCID FLOWS		Course contents (assuming 50 minutes lectures, total 40 lectures): Introduction: Continuity equation, Navier-Stokes equations, Bernoulli equation; (1 lecture) Vorticity dynamics: Vortex lines and tubes, kinematic results for vorticity, vorticity equation, Hill's spherical vortex, circulation, Kelvin's circulation theorem, Helmholtz theorems, Helmholtz's kinematic decomposition, Biot-Savart law, Inviscid motion of point vortices, line and sheet vortices, image vorticity, Vortex momentum, creation of vorticity ; (11 lectures) Potential flows: Stream function and velocity potential, complex analysis, standard flow patterns, circle theorem, integral momentum theorem, method of images, conformal transformations (including Jowkowski transformation, Schwarz-Christoffel theorem), axisymmetric and three-dimensional potential flows, unsteady potential flows, principle of virtual mass; (14 lectures)Interfacial waves and free-surface flows: Small amplitude free surface waves, engineering wave properties, standing waves, small-amplitude interfacial waves, non-linear theory of shallow-water waves, method of characteristics, bores and hydraulic jumps;(9 lectures) Elements of bubble dynamics: Rayleigh equation, Rayleigh-Plesset equation, cavitation and bubble breakdown – (2 lectures) Compressible inviscid flows: Waves in inviscid perfect gas, small-amplitude waves (acoustics); (3lectures) **Course Reference** : 1. Milne-Thomson, L. M. “Theoretical Hydrodynamics;, Dover; 2. Milne-Thomson, L. M.; Theoretical Aerodynamics; 3. Vallentine, H. R.;Applied Hydrodynamics, Butterworths; 4. Liepmann, H. W. and Roshko, A.;Elements of Gasdynamics, Dover; 5. Batchelor, G. K.; Introduction to Fluid Dynamics”, Cambridge Univ Press; 6. Panton, R. L.;Incompressible Flow, Wiley; 7. Dean, R. G. and Dalrymple, R. A. ldquo;Water Wave Mechanics rdquo;, World Scientific; 8. Saffman, P. G. Vortex Dynamics, Cambridge Univ Press.
ME699	M TECH THESIS	-0-0--	M. Tech. Thesis
ME699.	M TECH THESIS (FOR DUAL DEGREE ONLY)	0-0-0--9	M TECH THESIS (FOR DUAL DEGREE ONLY)
ME720	THERMODYNAMICS OF CONTINUOUS MEDIA	3-0-0-0-4	1. Foundations of continuum thermodynamics 1.1 Geometry of continuous bodies: kinematics; singular surfaces; strain compatibility (3)1.2 Balance of mass and momentum; the concept of stress (1)1.3 The first law of thermodynamics: energy; work; heat (1)1.4 The second law of thermodynamics: temperature; entropy; the ClausiusDuhem inequal ity (4)1.5 Constitutive theory1.5.1 Material frame indifference and material symmetry (1)I1.5.2 Equilibrium response (1)1.5.3 Dynamic response: linear irreversible thermodynamics (Onsanger's relations) ; dissipation potential; maximum dissipation principle (3)1.6 Thermodynamic equilibrium; stability (4)2. Rigid conductors 2.1 Constitutive equations; Fourier 's law (2)2.2 Boundary value problems (2)3.

			Thermoelasticity 3.1 Constitutive equations; linear thermoelasticity (2)3.2 Boundary value problems (2)3.3 Thermoelastic stability: buckling of beams and plates (2)4. Thermoplasticity 4.1 Constitutive equations: simple phenomenological models with work hardening (3)4.2 Onedimensional problems: adiabatic shear bands (4)5. Thermodynamics of surfaces5.1 Gibbs; treatment of surfaces (1)5.2 Surface energy, surface tension, and surface stress; capillarity (2)5.3 CalmHilliard type of theories for diffusive interfaces (2)5.4 Problems (can be from different sources, for e.g. adiabatic shock waves, phase transformations, grain growth, membrane mechanics) (4) (i) The Mechanics and Thermodynamics of Continuous :tvledia, M. Silhavy, Springer, 1997.(ii) An Introduction to Thermomechanics, H. Ziegler, NorthHolland, 1983.(iii) The Mechanics and Thermodynamics of Continua, M. E. Gurtin, E. Fried, and L. Anand Cambridge, 2010.(iv) Theory of Thermal Stresses, B. A. Boley and J. H. Weiner , Dover , 1997.(v) The Physics and Mathematics of Adiabatic Shear Bands, T. W. Wright , Cambridge, 2002. (vi) Statistical Thermodynamics of Surfaces, Interfaces, and Membranes, S. A. Safran, Addison Wesley, 1994.
ME721	THEORY OF PLASTICITY	3-0-0--4	Yield surfaces. Deformation and flow theories; Theory of plastic constitutive equations; Axisymmetric and spherically symmetric problems; Slipline theory and application to problems of extrusion, drawing and indentation; Wave propagation in plastic materials.
ME721A	THEORY OF PLASTICITY	3-0-0-0-9	Yield surfaces. Deformation and flow theories; Theory of plastic constitutive equations; Axi symmetric and spherically symmetric problems; Slipline theory and application to problems of extrusion, drawing and indentation; Wave propagation in plastic materials.
ME723	WAVE PROPAGATION IN SOLIDS	3-0-0--4	Waves in infinite and semiinfinite elastic media. Reflection and refraction atplane interface. Dispersion of waves in bounded solids. Waves in rods and plates. Solution of transient problems. Rayleigh waves. Waves in anisotropic materials. Introduction to waves in viscoelastic and plastic media.
ME723A	WAVE PROPAGATION IN SOLIDS	3-0-0-0-9	Waves in infinite and semiinfinite elastic media. Reflection and refraction atplane interface. Dispersion of waves in bounded solids. Waves in rods and plates. Solution of transient problems. Rayleigh waves. Waves in anisotropic materials. Introduction to waves in viscoelastic and plastic media.
ME724	MECHANICS OF BIOLOGICAL MEMBRANES	3-0-0-0-4	1. Organisation of Animal cells: Structure and function of cell membrane. Roll of fluid lipid bilayers in cell functionality. Discussion on the experimental methods of study membranes.2. A brief review of diffrential geometry concepts.3. Development of the electicity models of membranes. Applications of the theory to the determination of the stable equibilirium shapes of red blood cells. Application of the theory to equilibrium shapes of phase separated fluid lipid bilayers.4. A discussion on the adhesion of vecicles and cells. Role of membrane elasticity to adhesion.5. Interplay between membrane elasticity and protein binding via a combined mechanical and thermodynamic model. **Course Reference**:

			1. B Albert at zl.; Molecular biology of the cell. Garland Science, NY, 2002 (fourth edition); 2. J. N. Israelachvili, Intermolecular and Surface Forces: With Applications to Colloidal and Biological Systems. Academic Press, 1992 (second edition); 3. R. Lipowsky and E. Sackmann, Structure and Dynamics of Membranes, Handbook of Biological Physics Vol. 1, Elsevier, Amsterdam, 1995; 4. S. A. Safran, Statistical Thermodynamics of Surfaces, Interfaces, and Membranes, Westview Press, 2003.
ME724A	MECHANICS OF BIOLOGICAL MEMBRANES	3-0-0-0-9	1. Organisation of Animal cells: Structure and function of cell membrane. Roll of fluid lipid bilayers in cell functionality. Discussion on the experimental methods of study membranes; 2. A brief review of diffrential geometry concepts; 3. Development of the electicity models of membranes. Applications of the theory to the determination of the stable equibilirium shapes of red blood cells. Application of the theory to equilibrium shapes of phase separated fluid lipid bilayers; 4. A discussion on the adhesion of vecicles and cells. Role of membrane elasticity to adhesion; 5. Interplay between membrane elasticity and protein binding via a combined mechanical and thermodynamic model. **Course Reference:** 1. B Albert at zl.; Molecular biology of the cell. Garland Science, NY, 2002 (fourth edition); 2. J. N. Israelachvili, Intermolecular and Surface Forces: With Applications to Colloidal and Biological Systems. Academic Press, 1992 (second edition); 3. R. Lipowsky and E. Sackmann, Structure and Dynamics of Membranes, Handbook of Biological Physics Vol. 1, Elsevier, Amsterdam, 1995; 4. S. A. Safran, Statistical Thermodynamics of Surfaces, Interfaces, and Membranes, Westview Press, 2003.
ME725	MICRO-MECHANICS	3-0-0-0-4	1. Introduction: Defects in continua, their properties and characterization (1 lecture); 2. Review of linear elastostatics. Defects. Eigenstrains. Static Green's functions. Superposition principle. (2 lectures); 3. Conservation laws. Niether's theorem. (4 lectures); 4. Application to linear elastostatics. The Eshelby tensor: physical interpretation, invariants, principal values. (6 lectures); 5. Linear elasticity with defects. Holes, inclusions and dislocations. Interaction of defects. Equivalent macroscopic properties. (6 lectures); 6. Inhomogeneous elastostatics. Anisotropic elastostatics. Equivalent macroscopic properties. Coupled problems: Thermoelasticity (6 lectures); 7. Elastodynamics of defected solids. Vvave motion. (6 lectures); 8. Dissipative systems: Viscoelasticity. Neutral action method. (5 lectures); 9. Conservation principles in bars, shafts, beams and plates (6 lectures) **Course Reference**: 1. R. Kienzler and G. Herrmann. Mechanics in material space, with application to defectand fracture mechanics. Springer; 2. T. Mura. Micromechanics of defects in solids. Martinus Nijhoff; 3. S. Nemat Nasser and M. Hori. Micromechanics: Overall properties of heterogeneous materials. North Holland.
ME725A	MICROMECHANICS	3-0-0-0-9	1. Introduction: Defects in continua, their properties and characterization (1 lecture); 2. Review of linear elastostatics. Defects. Eigenstrains. Static Green's functions. Superposition

			principle. (2 lectures); 3. Conservation laws. Niiether's theorem. (4 lectures); 4. Application to linear elastostatics. The Eshelby tensor: physical interpretation, invariants, principal values. (6 lectures); 5. Linear elasticity with defects. Holes, inclusions and dislocations. Interaction of defects. Equivalent macroscopic properties. (6 lectures); 6. Inhomogeneous elastostatics. Anisotropic elastostatics. Equivalent macroscopic properties. Coupled problems: Thermoelasticity (6 lectures); 7. Elastodynamics of defected solids. Vvave motion. (6 lectures); 8. Dissipative systems: Viscoelasticity. Neutral action method. (5 lectures); 9. Conservation principles in bars, shafts, beams and plates (6 lectures) **Course Reference**: 1. R. Kienzler and G. Herrmann. Mechanics in material space, with application to defectand fracture mechanics. Springer; 2. T. Mura. Micromechanics of defects in solids. Martinus Nijhoff; 3. S. Nemat Nasser and M. Hori. Micromechanics: Overall properties of heterogeneous materials. NorthHolland.
ME726	HAMILTONIAN MECHANICS AND SYMPLECTIC ALGORITHMS	3-0-0--4	Part 1: a) Some relevant definitions and results in the theory of differentiable manifolds, smooth vector fields, differential forms, exterior) calcu lus (differentiation and integration using differential forms), differential equations and their associated flow maps, Symplectic manifolds. Part 1: b) Brief review of Hamiltonian mechanics (Lagrange's vs Hamilton's Equations), Canonical Transformation, Legendre Traus formation, Symplectic Transformations, Some definitions and results in the theory of Continuous Groups for Symmetries and Conserved quantities, PoincareCartan invariant, The Hamilton Jacobi Partial Differential Equation. Integrable systems (simple examples). Part 2: a) Some basic notions of numerical algorithms (order conditions etc). Examples of Numerical methods, Symplectic Integra tors, and Geometric integTators. Applications to simple problems in particle dynamics and a two-body problem. Part 2: b) Symplectic Runge Kutta methods, Generating Function for Symplectic Rm1geKutta Methods and Symplectic Ivlethods Based on it. Variational Integrators. Introduction to Hamiltonian Perturbation theory (if time permits). Discussion on some open problems in symplectic algorithms and a brief discussion on geometric numerical integration with some applications to mechanical systems. **Course Reference**: 1. Arnold, V. I., 1989. Mathematical Methods of Classical Mechanics. Springer. Second edition. [Text book: for part 1 only sections 18, 3241, 4448, for part 2 only sections 1317, 19]; 2. Leimkuhler, B., Reich S, 2004. Simulating Hamiltonian Dynamics. Cambridge University Press [Textbook: for part 2 chapters 1, 2, 47,9]; 3. Hairer, E., Lubich, C., valmer, G., 2006. Geometric Numerical Integration: Structure Preserving Algorithms for Ordinary Differential Equations. Springer.
ME726A	HAMILTONIAN MECHANICS AND SYMPLECTIC ALGORITHMS	3-0-0-0-9	Part 1: a) Some relevant definitions and results in the theory of differentiable manifolds, smooth vector fields, differential forms, exterior) calcu lus (differentiation and integration using differential forms), differential equations and their associated

			flow maps, Symplectic manifolds. Part 1: b) Brief review of Hamiltonian mechanics (Lagranges vs Hamiltons Equations), Canonical Transformation, Legendre Taraus formation, Symplectic Transformations, Some definitions and: results in the theory of Cont.inuous Groups for Symmet.ries and Conserved quantities, Poincare Cartan invariant, The HamiltonJacobi Partial Differential Equation. Integrable systems (simple examples). Part 2: a) Some basic notions of numerical algorithms (order conditions etc). Examples of Numerical methods, Symplectic Integra tors, and Geometric integrators. Applications to simple problems in particle dynamics and a two-body problem. Part 2 b) Symplectic RungeKutta methods; Generating Function for Symplectic RangeKutta Methods and Symplectic methods based on it. Variational Integrators. Introduction to Hamiltonian Perturbation theory (if time permits). Discussion on some open problems in symplectic algorithms and a brief discussion on geometric numerical integration with some applications to mechanical systems.
ME727	COMPOSITE MATERIALS	3-0-0--4	Structures and method of preparation of fibres and fibre reinforced composites. Micromechanics, and prediction of elastic constants; Strength of composites; Properties of laminated composites and their constitutive equations; Laminates; Interfacial mechanics and properties; Applications.
ME727A	COMPOSITE MATERIALS	3-0-0--4	Structures and method of preparation of fibres and fibre reinforced composites. Micromechanics, and prediction of elastic constants; Strength of composites; Properties of laminated composites and their constitutive equations; Laminates; Interfacial mechanics and properties; Applications.
ME728	FRACTURE AND FATIGUE	3-0-0--4	Fracture: Energy release rate, crack tip stresses and deformation fields, plasticzone, Elastoplastic fracture through Jintegral and CTOD, Dynamic fracture, Testing for Fracture. Toughness. Fatigue: Crack nucleation and growth, Fatigue life prediction, Statistical analysis.
ME728A	FRACTURE AND FATIGUE	3-0-0-0-9	Fracture: Energy release rate, crack tip stresses and deformation fields, plasticzone, Elastoplastic fracture through Jintegral and CTOD, Dynamic fracture, Testing for Fracture. Toughness. Fatigue: Crack nucleation and growth, Fatigue life prediction, Statistical analysis.
ME729	MODELLING OF MECHANICAL PROPERTIES OF MATERIALS	3-0-0--4	Introduction, Homogenisation, Ductile Materials, Dislocations, single crystal plasticity, Size effects on mechanical properties, Thermodynamics of constitutive modelling, Examples of constitutive models, Modelling of very small structures.
ME741	COMBUSTION ENGINES & AIR POLLUTION	3-0-0-0-4	Thermochemistry, Chemical Equilibrium, Kinetics; Laminar and Tarbulent Flame propagation in SI Engines, Unburned and Burned Mixture States, Flame Quenching; Fuel Injection, Spray Atomization, Penetration and Evaporation, FuelAirMixing and Burning Rates in CI Engines; Pollutant Formation in Engines, Zeldovich Mechanism, Soot Formation; Vehicle Emissions and standards; Emission control

			Technologies, Catalytic Control, Engine Design and Fuel effects, New Advances; Emission Measurement
ME741A	COMBUSTION ENGINES & AIR POLLUTION	3-0-0-0-9	Thermochemistry, Chemical Equilibrium, Kinetics; Laminar and Tarbulent Flame propagation in SI Engines, Unburned and Burned Mixture States, Flame Quenching; Fuel Injection, Spray Atomization, Penetration and Evaporation, Fuel Air Mixing and Burning Rates in CI Engines; Pollutant Formation in Engines, Zeldovich Mechanism, Soot Formation; Vehicle Emissions and standards; Emission control Technologies, Catalytic Control, Engine Design and Fuel effects, New Advances; Emission Measurement.
ME742	BOILING & CONDENSATION	0-0-0--4	Pool boiling: Nukiyama Experiment, theory of vapour bubble formation, Mechanism of CHF, various models and correlations. Flow Boiling, Homogeneous, and hetrogeneous models, Boiling enhancement techniques. Heat Pipes. Design of boilers, Film and dropwise condensation. Nusselt's analysis of laminar film condensaion on vertical flat plate, single horizontal tube and vertical array oftubes. Laminar wavy and turbulent film condensation. Film condensation inside horizontal tubes, condensation enhancement techniques, design of condensers, special topics: Computer simulation of boiling.
ME743	FUEL CELLS	3-0-0-0-4	(approximate number oflectures in brackets)1. Fundamentals: Review of classical thermodynamics; introductory electrochemistry; principles of chemical and electrochemical kinetics; transport phenomena in electrochemical systems [14].2. Analyses of fuel cells: Classical thermodynamic analyses of fuel cell systems; analyses of fuel cell kinetics; quantification of fuel cell performance [14].3. Computational/experimental techniques: Conservation and rate equations; approximate analytical treatment of fuel cell systems; scope and limitations of onedimensional analyses; introduction to computational fluid mechanics of fuel cell systems; measurement of fuel cell performance; lab visits; introduction to electrochemical impedance spectroscopy [10].4. Special topics: Direct methanol fuel cell; microbial fuel cell; hydrogen generation and storage; limitations, recent advances and challenges in fuel cell research [4]. **Course Reference**:1. Fuel Cell Systems Explained, J. Larminie and A. Dicks (John Wiley & Sons, 2003, USA); 2. Fuel Cell Fundamentals, R;Hayre, SW. Cha, W. Colella, F. B. Prinz (John Wiley and Sons, 2005, USA); 3. Fuel Cell Engines, M. M. Mench (John Wiley and Sons, 2008, USA); 4. Fuel Cells: From Fundamental to Applications, S. Srinivasan (Springer, 2006, USA); 5. Principles of Fuel Cells, X. Li (CRC Press, 2005, USA); 6. Fuel Cells: Principles and Applications, B. Viswanathan and M.A. Scibioh (Universities Press, 2006, India); 7. PEM Fuel Cells: Theory and practice, F. Barbir (Elsevier Academic Press, 2005, USA); 8. HighTemperature Solid Oxide Fuel Cells: Fundamental, Design and Applications, S. C.Singhal, K. Kendall (Elsevier Science, 2004, USA); 9. Transport Phenomena in Fuel cells, Ed. B. Sunden and M. Faghri (WIT Press, 2005, UK); 10. Fundamentals of Electrochemistry, V. S. Bagotsky (John Wiley & Sons, 2006,

			USA
ME744	Combustion and Reacting Flow	3-0-0-0-4	(approximate number of lectures in brackets): I. Thermodynamic idealization of reacting, and high temperature systems: classical and statistical thermodynamics review [6]; 2. Chemical kinetics, heterogeneous chemistry, kinetics of hydrocarbon fuels, kinetics of pollutant formation, sensitivity analysis [6]; 3. Review of multicomponent mass transfer, radiation in participating media [5]; 4. Coupling of thermodynamics, kinetics, and transport for idealized reactors [3]; 5. Approximate modeling of reacting systems; Numerical solution of coupled, stiff differential equations; computer simulation of reacting systems; laminar premixed and diffusion flames, chemical vapor deposition, hydrocarbon reforming processes, porous media reactor, membrane reactor [8]; 6. Thermal decomposition, ignition, and detonation [2]; 7. Ignition and combustion of solid propellant; approximate modeling of laser and plasma Ignition ; 8. Environmental impact; pollutant formation and control; exergybased analysis [3]; 9. Experimental techniques, theories of spectroscopy and mass spectrometry [3]; I0. Futuristic technologies and advanced topics; possible topics: biogas reforming and combustion, coal combustion, lean combustion, flameless combustion, oxyfuel combustion, chemical looping combustion, carbon nanotube synthesis, burner design [3] **Course Reference**: 1. Fundamentals of Combustion, D. P. Mishra (PrenticeHall India, 2008); 2. Combustion, Glassman, Yetter (Associated Press, 2008); 3. Irreversible phenomena, K. Terao. (Springer, 2007); 4. Combustion, Warnatz, Mass, Dibble (Springer, 2006); 5. Combustion physics, C. K. Law (Cambridge, 2006); 6. Dynamics of Combustion Systems, A. K. Oppenheim (Springer, 2006); 7. Chemical kinetics and reaction dynamics, S. K. Upadhyay (Springer, 2006); 8. Chemically Reacting Flow, Kee, Coltrin, Glarborg (WileyInterscience, 2003); 9. An Introduction to Combustion, S. R. Turns (McGrawHill, 2000, international edition); 10. Combustion theory, F. A. Williams (Benjamin/Cummings 1985).
ME751	COMPUTER AIDED ENGINEERING DESIGN	3-0-0--4	Methodology of interactive, graphical, engineering design; Discretization, optimization, simulation in CAED. Design of curves and surfaces. Applications in conveyor systems, sheet metal working, tool design, pumps etc. Design of volumes. Intersection of surface and interference of volumes.
ME751A	COMPUTER AIDED ENGINEERING DESIGN	3-0-0-0-9	Methodology of interactive, graphical, engineering design; Discretization, optimization, simulation in CAED. Design of curves and surfaces. Applicationsin conveyor systems, sheet metal working, tool design, pumps etc. Design ofvolumes. Intersection of surface and interference of volumes.
ME752	OPTIMIZATION METHODS IN ENGINEERING DESIGN	3-0-0--4	Classical optimization methods, unconstrained minimization; Univariate, conjugate direction, gradient and variable metric methods, constrained minimization, Feasible direction and projections. Integer and Geometric programming, genetic algorithms, simulated annealing techniques, design applications.

ME752A	OPTIMIZATION METHODS IN ENGINEERING DESIGN	3-0-0-0-9	Classical optimization methods, unconstrained minimization; Univariate, conjugate direction, gradient and variable metric methods, constrained minimization, Feasible direction and projections. Integer and Geometric programming, genetical gorithms, simulated annealing techniques, design applications.
ME756	VIBRATION CONTROL	3-0-0--4	Factors affecting level of vibration, vibration reduction at the source, vibration control by structural design, selection of materials. Vibration control by additive damping; Dynamic vibration absorbers, vibration and shock isolators, Active control.
ME756A	VIBRATION CONTROL	3-0-0-0-9	Factors affecting level of vibration, vibration reduction at the source, vibration control by structural design, selection of materials. Vibration control by additive damping; Dynamic vibration absorbers, vibration and shock isolators, Active control.
ME757	DYNAMICS OF ROTATING MACHINERY	3-0-0--4	Rotorbearing interaction. Flexural vibration, critical speeds of shafts, Effectsof anisotropic bearings, unbalanced response of an assymetric shaft. Gyroscopic effects. Aerodynamic effects. Equivalent discrete system. Geared and branched systems. Fluid film bearings: Steady state characteristics of bearings. Rigidand flexible rotor balancing. Measurement techniques.
ME757A	DYNAMICS OF ROTATING MACHINERY	3-0-0-0-9	Rotor bearing interaction. Flexural vibration, critical speeds of shafts, Effects of anisotropic bearings, unbalanced response of an assymetric shaft. Gyroscopic effects. Aerodynamic effects. Equivalent discrete system. Geared and branched systems. Fluid film bearings: Steady state characteristics of bearings. Rigidand flexible rotor balancing. Measurement techniques.
ME759	ADVANCED TOPICS IN NON TRADITINAL MACHINING PROCESS	3-0-0-0-4	A brief review of nontraditional machining processes, Analysis of mechanical, thermal and Electrochemical type nontraditional machining processes. Analysis of micromachining processes. Tool design for selected nontraditional machining processes. Modeling and simulation of selected processes. A comparative studyof various processes. Application of CNC concepts to nontraditional machining processes machines. Computer aided process planning of nontraditional processes.
ME761	COMPUTER AIDED MANUFACTURING	3-0-0--4	Direct numerical control (DNC) and computer numerical control (CNC): adapative control of manufacturing processes. Manufacturing system concepts. Computer processes monitoring and control, offline use of computers. Computer aided design. Computer process interface; programming, introduction to FMS.
ME761A	COMPUTER AIDED MANUFACTURING	3-0-0-0-9	Direct numerical control (DNC) and computer numerical control (CNC): adapative control of manufacturing processes. Manufacturing system concepts. Computer processes monitoring and control, offline use of computers. Computer aided design. Computer process interface; programming, introduction to FMS.
ME762	INTRODUCTION TO ROBOTICS	3-0-0--4	Types of Robots. Spatial transformation and kinematics of open chain linkages. Mobile robots, Actuators, sensors, programming and control. Applications motion planning, grasping and industrial automation.
ME762A	INTRODUCTION	3-0-0-0-9	Types of Robots. Spatial transformation and kinematics of

	TO ROBOTICS		open chain linkages. Mobile robots, Actuators, sensors, programming and control. Applications motion planning, grasping and industrial automation.
ME763	ROBOT MANIPULATORS: DYNAMICS AND CONTROL	3-0-0--4	Review of robot manipulators. Manipulator kinematics, dynamics and control. Singularity and workspace analysis. Introduction to manipulator design.
ME763A	ROBOT MANIPULATORS: DYNAMICS AND CONTROL	3-0-0-0-9	Review of robot manipulators. Manipulator kinematics, dynamics and control. Singularity, and workspace analysis. Introduction to manipulator design.
ME765	MANUFACTURING AUTOMATION	3-0-0--4	Automation strategies, flow lines, automated assembly systems, transfer systems; Vibratory bowl feeders, nonvibratory feeders. Part orienting, feedtrack, part placing and part escapement systems; Programmable automation, industrial robotics; Flexible manufacturing systems; Automation equipment.
ME765A	MANUFACTURING AUTOMATION	3-0-0-0-9	Automation strategies, flow lines, automated assembly systems, transfer systems; Vibratory bowl feeders, nonvibratory feeders. Part orienting, feedtrack, part placing and part escapement systems; Programmable automation, industrial robotics; Flexible manufacturing systems; Automation equipment.
ME766	ROBOT MOTION PLANNING	3-0-0--4	Configuration spaces of mobile vehicles and manipulators, Geometric modelling and sensor- based map building. Path planning and obstacle avoidance. Object manipulation and grasping. Design of user interfaces and simulation. Algorithms for assembly and biological aspects of motion and intelligence.
ME766A	ROBOT MOTION PLANNING	3-0-0-0-9	Configuration spaces of mobile vehicles and manipulators, Geometric modelling and sensor- based map building. Path planning and obstacle avoidance. Object manipulation and grasping. Design of user interfaces and simulation. Algorithms for assembly and biological aspects of motion and intelligence.
ME767	EVOLUTIONARY ALGORITHMS IN SEARCH & OPTIMIZATION	3-0-0--4	Traditional optimization methods. Simple genetic algorithms reproduction, crossover and mutation. Analysis of GA operators; Deception; Multimodel and multi objective optimization; Engineering applications. Introduction with applications for Evolution strategy and Simulated annealing.
ME769A	ADVANCED TOPICS IN ROBOTICS	3-0-0-0-9	Advanced techniques of kinematics and dynamics of mechanical systems. Parallel actuated and closedloop manipulators. Redundant manipulators. Mobile robotes and path planning. Complaint motion and grasping. Sensing and vision. Nonlinerar control of robots. Any other relevant topic.
ME770	MATERIALS SELECTION IN MECHANICAL DESIGN	3-0-0--4	The evolution of engineering materials; Materials and the design process; Functional requirements of engineering materials; Materials selection based onproperties alone; Materials selection based on properties & shape; Processing, materials & design; Materials property data. Latest developments in the useof materials; New materials; Case studies.
ME770A	MATERIALS SELECTION IN	3-0-0-0-9	The evolution of engineering materials; Materials and the design process; Functional requirements of engineering

	MECHANICAL DESIGN		materials; Materials selection based onproperties alone; Materials selection based on properties & shape; Processing, materials & design; Materials property data. Latest developments in the useof materials; New materials; Case studies.
ME771	SMART MATERIALS AND STRUCTURE	3-0-0-0-4	Materials for both actuation and sensing: Piezoelectric Materials, Magnetostrictive Materials, Materials for actuation: Shape Memory alloys Magnetic shape memory material, Electro/Magneto rheological fluids; Materials for sensing: Optical fibre; Composite smart materials and micromodelling related issues; Energy based approach: Hellinger Reissner Principle, Variational Formulation, Finite Elements Modelling of Vibration of smart Laminates; state space based analysis & designof smart controllers, Concepts of Controllability & observability; Pole placement Techniques; Intelligent system with integrated sensors & actuators; Selfsensing actuators; Placement of Smart Actuators/Sensors Vibration damping.
ME771A	SMART MATERIALS AND STRUCTURE	3-0-0-0-9	Materials for both actuation and sensing: Piezoelectric Materials, Magnetostrictive Materials, Materials for actuation: Shape Memory alloys Magnetic shape memory material, Electro/Magneto rheological fluids; Materials for sensing: Optical fibre; Composite smart materials and micromodelling related issues; Energy based approach: Hellinger Reissner Principle, Variational Formulation, Finite Elements Modelling of Vibration of smart Laminates; state space based analysis & designof smart controllers, Concepts of Controllability & observability; Pole placement Techniques; Intelligent system with integrated sensors & actuators; Selfsensing actuators; Placement of Smart Actuators/Sensors Vibration damping.
ME773	GRANULAR MATERIALS	3-0-0-0-4	1. Introduction to granular materials: Illustrative examples; 2. Revision of continuum mechanics; 3. Materials with yield strength: I IohrCoulolllb and Drucker Prager materials; 4. Statics: Coulomb's, J ansseu's and Walker's method. Volume averaging; 5. Application: Hoppers, Dmns, Landslides alld Ast.eroids; 6. Micromechanical behavior: Particleparticle interaction. Meanfield theory; 7. Other features: Closepacking, Crystallization, Force chains, Shear banding; 8. Slow dense flow: Plasticity theory; 9. Application: Flows in Hoppers and Buukers; 10. Rapid granular flow: Smooth inelastic particles; 11. Examples: Plane Couette flow, Inclined cbntes; 12. Rapid granular flow: Rough inelastic particles; 13. Mixing and segregation: Brazilnut effect, Rotating drum and Avalanches; 14. Effect of air: Porous beds. Barchau d 111Hud Homglasses; 15. Introduction to computational modeling.
ME773A	GRANULAR MATERIALS	3-0-0-0-9	1. Introduction to granular materials: Illustrative examples; 2. Revision of continuum mechanics; 3. Materials with yield strength: I IohrCoulolllb and Drucker Prager materials; 4. Statics: Coulomb's, J ansseu's and Walker's method. Volume averaging; 5. Application: Hoppers, Dmns, Landslides alld Ast.eroids; 6. Micromechanical behavior: Particleparticle interaction. Meanfield theory; 7. Other features: Closepacking, Crystallization, Force chains, Shear banding; 8. Slow dense flow: Plasticity theory; 9. Application: Flows in Hoppers and

			Buukers; 10. Rapid granular flow: Smooth inelastic particles; 11. Examples: Plane Couette flow, Inclined cbntes; 12. Rapid granular flow: Rough inelastic particle; 13. Mixing and segregation: Brazilnut effect, Rotating drum and Avalanches; 14. Effect of air: Porous beds. Barchaud 111 Hud Home glasses; 15. Introduction to computational modeling.
ME774	BIOMEMS AND MICROSYSTEMS TECHNOLOGY	3-0-0-0-4	Introduction to BioMEMS and Microsystems technology, Biochips/ biosensors and introduction to device fabrication, Introduction to Cell biology, DNA & Protein chemistry, Microfluidics, Biochip Sensors & detection methods, potential of Microfluidics and introductory continuum mechanics at small scales, Microarrays andLabonchip devices, Introduction to MEMS Design. Microfluidics: Continuum mechanics at small scales, Basics of microfluidics, Gas flows, liquid flows, boundary conditions, low Reynold’s no. flows, entrance effects, surface tension, electrokinetic techniques like electrophoresis, electro osmosis and dielectrophoresis, microfluids for internal flow eontrol (micropumps and microvalves, cfevice building and characterization), **Course Reference**: 1. Fundamentals of Microfabrication (Second Edition), Marc J. Madou, CRCpress Taylor and Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL334872724, 2002; 2. BioMEMS Technologies and Applications, Edited by Wanjun Wang, StevenA. Soper, CRC press Taylor and Francis Group, 6000 Broken Sound ParkwayNW, Suite 300, Boca Raton, FL334872724, 2006; 3. Biomolecular sensing, processing and analysis, Rashid Bashir, Steve T. Werely, Mauro Ferrari, Springer Science and Business Media LLC, 233Spring Street, New York, NY10013, USA, 2006.
ME774A	BIOMEMS AND MICROSYSTEMS TECHNOLOGY	3-0-0-0-9	Introduction to BioMEMS and Microsystems technology, Biochips/ biosensors and introduction to device fabrication, Introduction to Cell biology, DNA & Protein chemistry, Microfluidics, Biochip Sensors & detection methods, potential of Microfluidics and introductory continuum mechanics at small scales, Microarrays and Lab onchip devices, Introduction to MEMS Design. Microfluidics: Continuum mechanics at small scales, Basics of microfluidics, Gas flows, liquid flows, boundary conditions, low Reynold’s no. flows, entrance effects, surface tension, electrokinetic techniques like electrophoresis, electroosmosis and dielectrophoresis, microfluids for internal flow eontrol (micropumps and microvalves, device building and characterization), **Course Reference**:1. Fundamentals of Microfabrication (Second Edition), Marc J. Madou, CRCpress Taylor and Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL334872724, 2002; 2. BioMEMS Technologies and Applications, Edited by Wanjun Wang, StevenA. Soper, CRC press Taylor and Francis Group, 6000 Broken Sound ParkwayNW, Suite 300, Boca Raton, FL334872724, 2006; 3. Biomolecular sensing, processing and analysis, Rashid Bashir, Steve T. Werely, Mauro Ferrari, Springer Science and Business Media LLC, 233Spring Street, New York, NY10013, USA, 2006.

ME778	ENGINEERING ACOUSTICS AND ITS CONTROL	3-0-0--4	Wave propagation in solids and fluids. Admittance and impedance concepts for infinite and finite acoustic waveguides. Sound radiation from vibrating structures: Measurement of radiated power, elementary radiators, sound radiation frombending waves. Passive attenuation of structureborne sound: Damping models, effect of elastic interlayers, blocking masses, changes of material and crosssection. Active control of structure borne sound: Elements of frequency domain control system analysis and synthesis, wave absorbing controllers for rods, beams, and plates.
ME778A	ENGINEERING ACOUSTICS AND ITS CONTROL	3-0-0-0-9	Wave propagation in solids and fluids. Admittance and impedance concepts forinfinite and finite acoustic waveguides. Sound radiation from vibrating structures: Measurement of radiated power, elementary radiators, sound radiation from bending waves. Passive attenuation of structure borne sound: Damping models, effect of elastic interlayers, blocking masses, changes of material and crosssection. Active control of structure borne sound: Elements of frequency domain control system analysis and synthesis, wave absorbing controllers for rods, beams, and plates.
ME779	RAPID PROTOTYPING & TOOLING TECH.	3-0-0--4	Importance and overview of Rapid Prototyping ario Manufacturing; Process Chain; Solid modeling; Data. formats, conversion, checking, repairing and transmission; Part Slicing and Build orientation;Classification of Rapid prototyping (RP), tooling (RT) and manufacturing (RM) processes; Materials for RP/RTIRM; Operating principles and characteristics qf current and developing rapid prototyping, tooling and manufacturing processes; Use of rapid prototypes and tools in product design, development and service; Selection of rapid prototyping and tooling systems based on product requirements; Case studies. Chua, C.K., Leong, K.F., and Lim, C.S., 2003, Rapid Prototyping Principles and Applications, World Scientific. (second edition). Jacobs, P.F., 1992, Rapid Prototyping and Manufacturing Fundamentals of StereoLithography, Society of Manufacturing Engineers.Lu, L., Fuh, J., and Wong, Y.S., 2001, LaserInduced Materials and Processes for Rapid Prototyping, KLuwer. /Gebhardt, A., 2003, Rapid Prototyping; Hanser. Pham, D.T., and Demov, S.S., 2001, Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, SpringerVerlag.Pique, A., and Chrisey, D.B., 2002, DirectWrite Techno ogies for Rapid Prototyping Applications: Sensors, Electronics and Integrated Power Sources, Academic Press.Vcnuvinod, P.K., and Ma, W., 2004, Rapid Prototyping Laser Based and Other Technologies, Kluwer.
ME781	APPROXIMATE METHODS IN ENGINEERING MATHEMATICS	3-0-0-0-4	This course is an introduction to approximate mathematical methods in engineering. These methods provide powerful tools with which to approximately analyze omplicated/intractable engineer ing/scientific models. These approximate solutions are often very accurate and also provide insight into the underlying physics in an accessible manner. Finally, these approximate methods play a symbiotic role to computational analyses; these latter techniques typically falter near singularities, which is where approximate methods are most

			useful.1. Introduction to asymptotic approximat_ions (2lectures): Asymptotic relations; Convergent/divergen power series; Asymptotic series; Error estimates; Subdominance; Stokes; phenomenon.2. Asymptotic analysis of integrals (11 lectures): Integration by parts; Laplace's method; Watson's lemma; Method of stationary phase; Method of steepest descent; Application.3. Introducti0n to perturbation theory (4 lectures): Algebraic equations; Iteration and expan sion; Method of dominant balance; Regular and singular perturbation problems; J lescaling; Nonintegral powers.4. Eigenvalue problems (4 lectures): First and second order perturbation; Iviultiple roots; Degenerate roots; Application.5. Summation of series (3 lectures): Improvement of convergence; Divergent series; Pade approximation; Application.6. Boundary layer theory (7 lectures): Introduction to boundary layers; Formal procedure; Inner, outer and intermediate layers; Asymptotic matching; Higher order theory; Distinguished limits; Application.7. VVKB Theory (4 lectures): Formal procedure; Patched asymptotic approximation; Turning point problems. Application8. Multiplescale analysis (6 lectures): Resonance and secular behavior; Formal procedure; Reduction to WKB and boundary layer theory; Mathieu equation; Application. **Course Reference**: 1. Bender, C. M. and S. 0. Orszag, 1999. Advanced Mathematical Methods for Scientists and Engineers, Springer Verlag: New York, USA; 2. Hinch, E. J., 1991. Perturbation Methods, Cambridge U. Press: Cambridge, U.K.
ME781A	APPROXIMATE METHODS IN ENGINEERING MATHEMATICS	3-0-0-0-9	This course is an introduction to approximate mathematical methods in engineering. These methods provide powerful tools with which to approximately analyze complicated/intractable engineering/scientific models. These approximate solutions are often very accurate and also provide insight into the underlying physics in an accessible manner. Finally, these approximate methods play a symbiotic role to computational analyses; these latter techniques typically falter near singularities, which is where approximate methods are most useful. 1. Introduction to asymptotic approximations (2lectures): Asymptotic relations; Convergent/divergen power series; Asymptotic series; Error estimates; Subdominance; Stokes phenomenon; 2. Asymptotic analysis of integrals (11 lectures): Integration by parts; Laplace's method; Watson's lemma; Method of stationary phase; Method of steepest descent; Application; 3. Introduction to perturbation theory (4 lectures): Algebraic equations; Iteration and expan sion; Method of dominant balance; Regular and singular perturbation problems; lescaling; Nonintegral powers; 4. Eigenvalue problems (4 lectures): First and second order perturbation; Iviultiple roots; Degenerate roots; Application.5. Summation of series (3 lectures): Improvement of convergence; Divergent series; Pade approximation; Application.6. Boundary layer theory (7 lectures): Introduction to boundary layers; Formal procedure; Inner, outer and intermediate layers; Asymptotic matching; Higherorder theory; Distinguished limits; Application; 7. vVKB Theory (4 lectures): Formal procedure; Patched asymptotic approximation; Turning

			point problems. Application; 8. Multiple scale analysis (6 lectures): Resonance and secular behavior; Formal procedure; Reduction to WKB and boundary layer theory; Mathieu equation; Application. **Course Reference**: 1. Bender, C. M. and S. 0. Orszag, 1999. Advanced Mathematical Methods for Scientists and Engineers, Springer Verlag: New York, USA; 2. Hinch, E. J., 1991. Perturbation Methods, Cambridge U. Press: Cambridge, U.K.
ME799	PHD THESIS	-0-0--	Ph. D. Thesis
ME850	BASIC CONTROL SYSTEMS FOR MECHANICAL ENGINEERS	3-0-0-0-4	1. Elementary review of dynamic systems. Equations of motion. Numerical solution of ODEs. Linearization.Stability. (5 lectures)2. Laplace transforms and inverse Laplace transforms. Block diagrams. Transfer functions. Feedback loops. poles and zeros. Transient responses. Stability. The RouthHu rwitz criterion. Nonminimum phase systems and their transient responses. Steady state responses. (7 lectures)3. Root locus plots. Nyquist plots. Bode plots. Implications for transient responses. (5 lectures)4. Compensators. Lead and lag compensators. PID controllers. Tuning rules. (4 lectures)5. Stabilization using a stable controller: motivation and sample problems. (3 lectures)6. Discrete time systems. Stability. (2 lectures)7. State space. Standard form for an LTI system. General solution. Controllability and observability. Pole placement. Connections with classical control. (8 lectures)8. Introduction to optimal control. The linear quadratic regulator. (2 lectures)9. Introduction to time delayed control. (2 lectures)10. Simulations of nonlinear systems with linearization- based controllers. Case studies from the literature as time permits. (4 lectures) In addition, the course will have a design-oriented project which requires a level of maturity appropriate for a postgraduate class. **Course Reference**: 1. K. Ogata. Modern Control Engineering. (PHI); 2. F. Golnaraghi and B. C. Kuo. Automatic Control Systems. (Wiley).
ME850A	BASIC CONTROL SYSTEM FOR MECHANICAL ENGINEERS	3-0-0-0-9	1. Elementary review of dynamic systems. Equations of motion. Numerical solution of ODEs. Linearization.Stability. (5 lectures); 2. Laplace transforms and inverse Laplace transforms. Block diagrams. Transfer functions. Feedback loops. poles and zeros. Transient responses. Stability. The RouthHu rwitz criterion. Nonminimum phase systems and their transient responses. Steady state responses. (7 lectures); 3. Root locus plots. Nyquist plots. Bode plots. Implications for transient responses. (5 lectures); 4. Compensators. Lead and lag compensators. PID controllers. Tuning rules. (4 lectures); 5. Stabilization using a stable controller: motivation and sample problems. (3 lectures); 6. Discrete time systems. Stability. (2 lectures); 7. State space. Standard form for an LTI system. General solution. Controllability and observability. Pole placement. Connections with classical control. (8 lectures); 8. Introduction to optimal control. The linear quadratic regulator. (2 lectures); 9. Introduction to time delayed control. (2 lectures); 10. Simulations of nonlinear systems with linearization-based controllers. Case studies from the literature

			as time permits. (4 lectures) In addition, the course will have a design-oriented project which requires a level of maturity appropriate for a postgraduate class. **Course Reference**: 1. K. Ogata. Modern Control Engineering. (PHI); 2. F. Golnaraghi and B. C. Kuo. Automatic Control Systems. (Wiley)
ME851	COMPLIANT MECHANISMS	3-0-0-0-4	Genesis of compliant mechanisms; glimpse of applications of compliant mechanisms; mobility analysis; large deformation analysis: continuum and discrete perspectives: finite element analysis, pseudo rigidbody analysis, and lumped analysis using spring lever and spring mass lever models; design of compliant mechanisms based on linkage synthesis methods, selection based methods, and structural optimization based methods; kinetoelastic maps and understanding limits of compliant mechanisms; static balancing of compliant mechanisms; applications in microsystems, precision engineering, biomedical, automotive, product design, etc.
ME851A	COMPLIANT MECHANISMS	3-0-0-0-9	Genesis of compliant mechanisms; glimpse of applications of compliant mechanisms; mobility analysis; large deformation analysis: continuum and discrete perspectives: finite element analysis,pseudo rigid body analysis, and lumped analysis using spring lever and spring-mass-lever models;design of compliant mechanisms based on linkage synthesis methods, selection based methods, and structural optimization based methods; kinetoelastic maps and understanding limits of compliant mechanisms; static balancing of compliant mechanisms; applications in microsystems, precision engineering, biomedical, automotive, product design, etc.
SE381	MICROSCALE THERMAL SCIENCES	3-0-0-0-4	Introduction: Micro Electro Mechanical Systems (MEMS), Micro channels, Heat pipes, Jets, Valves, Heat sinks, Solar cells, Bearings, Pumps, Flow sensors and actuators, Fins, Drug delivery systems; Transport Equations: Mass, Momentum, Heat and Charge transport equations, Multi component systems, Characteristic Nondimensional parameters; Microscale Heat Conduction: Microscale energy transport in solids, Heat transport in thin films and at solidsolid interfaces,Heat conduction in semiconductor devices and interconnects; Convective diffusion Phenomena: Enzyme substrate reactions, External flow, Internal flow, Channel flow with soluble or rapidly reacting walls, Flow past reacting flat plate; Solutions of Electrolytes: Electric double layer of Debye sheath, Electrokinetic phenomena,Electro osmosis, Electroosmotic microchannel systems, Electroosmotic Pumps; Surface Tension Driven Flows: Coating flows, Themo capillary flows, Thermo capillary pump, Diffuso capillary flows, Marangoni convection and instability;Modeling: Continuum model, Molecular model, Introduction to molecular dynamics simulations and direct simulation Monte Carlo method (DSMC); Assorted Journal Papers.
SE394	INTRODUCTION TO CONTINUUM MECHANICS	3-0-0-0-4	Vectors and Tensors; Stress, principal stresses, invariants, deviatoric stresses,plane stress, simplified theory; Strains and Deformation, rotation, material andspatial derivatives, deformation tensor, spin and rate of deformation, finitestrain

			and deformation, rotation and stretch tensors, compatibility conditions; General principles, continuity equation and momentum principles, transport theorems, virtual work, basic thermodynamics for solids; Constitutive equations, Rational mechanics approach, Classical elasticity, Generalized Hookes law,isotropy, hyperelasticity, thermal stresses, ideal frictionless fluids, Newtonian fluids, Stokes condition.
NT611	NUCLEAR POWER ENGINEERING I	3-0-0--4	Types of nuclear reactors. Heat generation in fuel elements and temperature distributions. Heat removal, Reactor coolants. Single phase and two- phase heat transfer. Boiling and flow regimes. Heat transfer and fluid flow correlations. Pressure, drops due to friction and pumping power. Reactor core
NT642	NON-DESTRUCTIVE EVALUATION	3-0-0-0-4	Introduction, various NDE techniques ultrasonics, eddy current, magnetic flux leakage, radiography, optical, tomographic extensions of classical NDE/NDT methods Radon inversion, data collection mechanisms, applications in industrial situations.
TA101A	ENGINEERING GRAPHICS		Introduction to sketching; Principal views, principles ofdimensioning Introduction to computer aided graphics Missing view, sectional view and assembly drawings Overview of pictorial representation, and isometric drawing in detail Perspective drawing Lines, planes, auxiliary view Relationship between lines and planes intersection oflines and planes Intersections of solids and development of lateral surfaces
TA202A	MANUFACTURING PROCESSES II	1-0-3-0-6	Engineering materials; Microstructure processing relationship; Solidification processes: molding and casting; Joining processes: welding, brazing, and soldering; Deformation processes: hot and cold working, bulk and sheet forming; Powder metallurgical processing: powder production, sintering; FeC phase diagram and heat treatment; Surface modification techniques: carburization, CVD, PVD. Specialized Infrastructure requirement: Rolling Mill, Pressure Die Casting Unit.
TA202N	MANUFACTURING PROCESSES	1-0-3--3	Engineering materials; Microstructure processing relationship; Solidification processes: molding and casting; Joining processes: welding, brazing, and soldering; Deformation processes: hot and cold working, bulk and sheet forming; Powder metallurgical processing: powder production, sintering; FeC phase diagram and heat treatment; Surface modification techniques: carburization, CVD, PVD. Specialized Infrastructure requirement: Rolling Mill, Pressure Die Casting Unit.

MATERIAL SCIENCE

Template?

DEPARTMENT OF MS			
Course ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
MS601	STRUCTURAL & MAGNETIC PROPERTIES OF MATERIALS	3-0-0--4	Crystal structure, Bonding of atoms, Crystal chemistry, Equilibrium thermodynamics, Phase equilibria, Phase transformations, Dia, Para, Ferro, Ferri and Anti ferromagnetism, Magnetic domains, Anisotropy effects, Magnetostriction, Measurement of magnetic properties, Soft and hard magnetic materials and their technology.
MS601A	STRUCTURAL & MAGNETIC PROPERTIES OF MATERIALS	3-0-0-0-9	Crystal structure, Bonding of atoms, Crystal chemistry, Equilibrium thermodynamics, Phase equilibria, Phase transformations, Dia, Para, Ferro, Ferri and Antiferromagnetism, Magnetic domains, Anisotropy effects, Magnetostriction, Measurement of magnetic properties, Soft and hard magnetic materials and their technology.
MS602	ELECTRICAL AND DIELECTRIC MATERIALS	3-0-0--4	Metallic conduction, Energy bands, Brillouin zones, Temperature dependence of metallic conductivity, Impurity contributions, Semiconductor materials, Doping effects, Law of mass action, Electrical resistivity and Hall effect measurements, Recombination Processes, pn junctions, MOS field effect transistors, Semiconductor technology, Point defects, Diffusion phenomenon, Ionic conduction, Temperature and (aliovalent) impurity effects, Superionic conductors and devices, Di, piezo and ferroelectric materials, Mechanisms of polarization, Dielectric parameters and their measurements.
MS602A	ELECTRICAL AND DIELECTRIC MATERIALS	3-0-0-0-9	Metallic conduction, Energy bands, Brillouin zones, Temperature dependence of metallic conductivity, Impurity contributions, Semiconductor materials, Doping effects, Law of mass action, Electrical resistivity and Hall effect measurements, Recombination Processes, pn junctions, MOS field effect transistors, Semiconductor technology, Point defects, Diffusion phenomenon, Ionic conduction, Temperature and (aliovalent) impurity effects, Superionic conductors and devices, Di, piezo and ferroelectric materials, Mechanisms of polarization, Dielectric parameters and their measurements.
MS603	MECHANICAL PROPERTIES OF MATERIALS	3-0-0-1-5	Stress and strain tensors, Elastic constants, Effect of structure on elastic behaviour, Elastic stress distributions, Viscosity and viscoelasticity in polymers, Yielding criteria, Dislocations and plastic deformation of metals and ceramics, Strengthening mechanisms, Creep, Brittle fracture in ceramics and glasses, Toughening of ceramics and composites, Fatigue, Mechanical testing, Strength and engineering design with brittle solids, Heat treatment, Powder processing.
MS603A	MECHANICAL PROPERTIES OF	3-0-0-0-9	Stress and strain tensors, Elastic constants, Effect of structure on elastic behaviour, Elastic stress distributions, Viscosity and

	MATERIALS		viscoelasticity in polymers, Yielding criteria, Dislocations and plastic deformation of metals and ceramics, Strengthening mechanisms, Creep, Brittle fracture in ceramics and glasses, Toughening of ceramics and composites, Fatigue, Mechanical testing, Strength and engineering design with brittle solids, Heat treatment, Powder processing.
MS604	CHARACTERIZATION OF MATERIALS	3-0-1--5	Crystallography, Reciprocal lattice, Diffraction methods, Electron microscopy, Metallography, Thermal analysis, Chemical analysis, Spectroscopic techniques, Laboratory sessions.
MS604A	CHARACTERIZATION OF MATERIALS	3-0-1-0-10	Crystallography, Reciprocal lattice, Diffraction methods, Electron microscopy, Metallography, Thermal analysis, Chemical analysis, Spectroscopic techniques, Laboratory sessions.
MS605	MATERIALS ENGINEERING	3-0-0--4	Solidification, Powder processing, Crystal growth, Heat treatment and microstructures, Nondestructive evaluation, Processing of glasses and polymers, Novel processing methods, Thin films, Surface phenomena and corrosion.
MS605A	MATERIALS ENGINEERING	3-0-0-0-9	Solidification, Powder processing, Crystal growth, Heat treatment and microstructures, Nondestructive evaluation, Processing of glasses and polymers, Novel processing methods, Thin films, Surface phenomena and corrosion.
MS606	ELECTRONIC MATERIALS		Classification, Crystal growth techniques, Wafer processing, Doping methods, Formation of oxide layer, CVD, MOCVD and MBE, Metallic contacts and interconnects, Lithography, Processing integration. Photonic materials solar cells, photodetectors, light emitting diodes, Superlattice structures, Materials for high frequency and high temperature devices, Application of linear and nonlinear dielectric materials, Electrooptic ceramics, Materials for signal processing, transducers and digital data storage, Superconducting materials and applications.
MS606A	ELECTRONIC MATERIALS		Classification, Crystal growth techniques, Wafer processing, Doping methods, Formation of oxide layer, CVD, MOCVD and MBE, Metallic contacts and interconnects, Lithography, Processing integration. Photonic materials solar cells, photodetectors, light emitting diodes, Superlattice structures, Materials for high frequency and high temperature devices, Application of linear and nonlinear dielectric materials, Electrooptic ceramics, Materials for signal processing, transducers and digital data storage, Superconducting materials and applications.
MS611	MATERIALS FOR ENERGY CONVERSION & STORAGE	3-0-0--4	Characteristics of solar radiation, Basic features of solar cells, Various junction configurations, pn homojunction, Schottky barrier, Heterojunction, Photo electrochemical cells, Desired material properties, Promising semiconductor materials, Various fabrication techniques, Solid state diffusion, Vacuum evaporation, Sputtering, Thermal oxidation, Chemical displacement, Plasma deposition, Energy storage devices.
MS614	ENGINEERING POLYMERS	3-0-0--4	Classification and structure of polymers, Glass transition, Linear viscoelasticity, Stress relaxation and dynamic experiments, Mechanical models, Superposition principles,

			Effect of structure on mechanical properties, Rubber elasticity, Yield and fracture.
MS617	INTRODUCTION TO NANOMATERIALS AND NANOTECHNOLOGY	3-0-0-0-4	Effects of confinement and finite size zero, one and two dimensional nanostructures(concepts of surface and interfacial energies), Intermolecular and interfacial forces in organic, polymeric, biological and aqueous systems Van derWaals, electrostatic, double layer, acid base, depletion interactions, hydrophobic force, layering, mesoscale thermodynamics, Gibbs treatment of interfaces, mesoscale fluid dynamics, thin soft films, mesoscale phenomena in soft matter and applications: adhesion, wetting, nucleation, Nanofabrication: patterning of soft materials by self organisation and other techniques, chemical selfassembly, artificial multilayers, cluster fabrication, Langmuir Blodget growth, Nano lithography, Scanning probe lithography, Micro contact printing, Synthesis of nanoparticles and films: solgel, hydrothermal, freeze drying, intercalation, attrition, ion implantation, Gas phase condensation, Chemical vapour deposition, Nanosuspensions ferro fluids, Compaction of nanocrystlline materials, Carbon nanotubes, short and long term applications and perspectives, Demonstration of some techniques in preparation and characterization of nanomaterials.
MS617A	INTRODUCTION TO NANOMATERIALS AND NANOTECHNOLOGY	3-0-0-0-9	Effects of confinement and finite size zero, one and two dimensional nanostructures(concepts of surface and interfacial energies), Intermolecular and interfacial forces in organic, polymeric, biological and aqueous systems Van der Waals, electrostatic, double layer, acid base, depletion interactions, hydrophobic force, layering, mesoscale thermodynamics, Gibbs treatment of interfaces, mesoscale fluid dynamics, thin soft films, mesoscale phenomena in soft matter and applications: adhesion, wetting, nucleation, Nanofabrication: patterning of soft materials by self organisation and other techniques, chemical self assembly,artificial multilayers, cluster fabrication, Langmuir Blodget growth, Nanolithography, Scanning probe lithography, Micro contact printing, Synthesis of nanoparticles and films: solgel, hydrothermal, freeze drying, intercalation, attrition, ionimplantation, Gas phase condensation, Chemical vapour deposition, Nanosuspensions ferrofluids, Compaction of nanocrystlline materials, Carbon nanotubes, short and long term applications and perspectives, Demonstration of some techniques in preparation and characterization of nanomaterials.
MS698	GRADUATE SEMINAR	----0	Graduate Seminar
MS698A	GRADUATE SEMINAR	0-0-0-0-0	Graduate Seminar
MS699	M TECH THESIS	----	M. Tech. Thesis
MS799	PHD THESIS	----	Ph. D. Thesis

MATERIAL SCIENCE AND ENGINEERING

MATERIALS SCIENCE & ENGINEERING

B.TECH.								Template No. MSE-1
	SEMESTER							
	1st	2nd	3rd	4th	5th	6th	7th	8th
C	MTH101A [11]	MTH102A [11]	ESO-1 [11] (ESO202A)	COM200A [05]	HSS-3 (Level-2) [09]	MSE304A [06]	DE-2 [09]	DE-4 [09]
O	PHY103A [11]	PHY102A [11]	ESO-2 [14] (ESO205A)	ESC201A [14]	MSE301A [06]	MSE305A [06]	DE-3 [09]	DE-5 [09]
U	CHM101A [03]	PHY101A [03]	MSE201A [11]	MSE202A [11]	MSE302A [09]	MSE312A [03]	OE-2 [09]	HSS-5 (Level-2) [09]
	ESC101A [14]	LIF101A [06]	SO-1 [06] (MSO203B)	MSE203A [09]	MSE303A [09]	MSE314A [03]	OE-3 [09]	OE-6 [09]
R	ENG112A/HSS-1 (Level-1) [11]	CHM102A [08]	HSS-2 (Level-1) [11]	MSE204A [06]	MSE311A [03]	MSE315A [03]	OE-4 [09]	OE-7 [09]
S	PE101A [03]	PE102A [03]	TA202A [06]	SO-2 [08] (PSO201A)	MSE313A [03]	HSS-4 (Level-2) [09]	UGP-3 (MSE497A)/ OE-5 [09]	UGP-4 [09] (MSE449A) (extra credit)
E		TA101A [09]			MSE300A [02]	UGP-2 (MSE398)/ DE-1 [09]		
S	-	-	-	TA201A [06]	ESO-3 [11] (ESO208A)	OE-1 [09]	-	-
				-	UGP-1 [04] (MSE349A) (extra credit)	-		
	53	51	59	59	52/56	48	54	45/54

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	90	Credits
Department Elective (DE)	:	45	Credits
Open Elective (OE)	:	63	Credits
SO/ ESO	:	50	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	421	Credits

REMARKS:

1) DE credits may include UGP-2.
2) OE credits may include UGP-3.
3) UGP-1 & UGP-4 are optional and do not count towards DE/OE credits.
4) Upto 36 OE credits may be waived from the minimum requirements for students opting for either Dual Degree or Double Major programme.

BT-MT (Category – A) *(from the same department)*					Template No. MSE-2
C	SEMESTER				
O	7th	8th	SUMMER	9th	10th
U R S	OE PG-1 [09]	OE PG-3 [09]	M.Tech. Thesis / DE PG 1/2 [18] (Optional)	M.Tech. Thesis [36]	M.Tech. Thesis [36]
E	OE PG-2 [09]	OE PG-4 [09]	-	-	-
S	DE PG-1 [09]*	DE PG-2 [09]*			
	27	27	18	36	36

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Component	:	54	Credits
Thesis Component	:	72	Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ DUGC Convener.
2) *If an MSE student has taken two PG-level DEs during the UG programme, those credits may be counted for DE PG-1 and 2 here. However, if no such PG courses have been taken during the UG programme, then the student will have to take two DE PG courses during the PG part of the programme.
3) Since registration for thesis and/or course credits is optional in the summer, those credits are not part of the minimum M.Tech. requirement.
4) Upto 36 OE credits may be used from the BT minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the BT programme and counted towards PG requirements.

BT-MT (PG Part – Category B) *(from other departments)*				Template No.MSE-3	
C					
O	7th	8th	SUMMER	9th	10th
U	OE PG-1 [09]	OE PG-3 [09]	M.Tech. Thesis [18]	M.Tech. Thesis [27]	M.Tech. Thesis [27]
R S E	OE PG-2 [09]	OE PG-4 [09]	-	PG -1 [09]	PG -2 [09]
S	18	18	18	36	36

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Component	:	54	Credits
Thesis Component	:	72	Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ DUGC Convener.
2) PG-1 and PG-2 may be done either in 7th and 8th Semester or 9th and 10th Semester with the permission of Supervisor/ DUGC Convener.
3) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech. part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
4) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the BT-MT dual degree programme. These will be waived from the parent department's BT programme requirements and counted towards PG requirements.

DOUBLE MAJOR		Template No. MSE-4
COURSES		
	Odd Semester	Even Semester
	Pre-Requisite	
	ESO205A [14]	-
	Mandatory MSE Courses	
	MSE201A [11]	MSE202A [11]
	MSE301A [06]	MSE203A [09]
	MSE302A [09]	MSE204A [06]
	MSE303A [09]	MSE304A [06]
	MSE311A/MSE313A [03]	MSE305A [06]
	MSE DE-1 [09]	MSE DE-2 [09]
	47	47

TOTAL MANDATORY CREDITS FOR SECOND MAJOR IN MATERIALS SCIENCE & ENGINEERING: 94 CREDITS

REMARKS:

1) It is preferred that students have exposure to ESO202A and PSO201A, but this is not mandatory.
2) Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.

MINOR	Template No.MSE-5
Title	FUNCTIONAL MATERIALS
COURSES	
	Any THREE from:
	MSE604A [09]
	MSE624A [09]
	MSE628A [09]
	MSE631A [09]
	MSE693A [09]
	27

DEPARTMENT OF MSE			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
MSE100	INTRODUCTION TO PROFESSION	2-0-0-0-0	Historical aspects of various materials, including some landmarks; Natural resources of materials; Cost, economics, energy, environmental and political issues relating to materials industry and applications; Importance of materials and their properties, performance and manufacturing processes in the development and growth of automotive, aerospace and railway sectors, electrical, electronicand telecommunication equipment/systems, energy sector, military hardware,structural and general engineering applications, biomedical/implant materialsetc.; Demonstrations/film shows related to selected materials and their characterization, properties and processing.
MSE200	THERMODYNAMICS OF MATERIALS	3-1-0-0-4	Heterogeneous and homogeneous systems, extensive and intensive properties, simple equilibrium; First Law of thermodynamics, constant volume and constant pressure processes;

			Spontaneous processes, entropy and quantification of irrversibility, properties of heat engines, thermodynamic temperature scale,Second Law of thermodynamics, criterion for equilibrium, Entropy and disorder, most probable microstate, configurational entropy and thermal entropy; auxiliary functions, Maxwells relations, Gibbs Helmholtz equation; Third Law of thermodynamics; variation of Gibbs energy with temperature and pressure, Clausius Clapeyron equation; thermodynamic properties of mixtures of ideal and imperfect gases; reactions in gas mixtures; reactions of pure condensed phases with gas mixtures standard Gibbs energy of reactions, Ellingham diagrams; Raoulfs and Henrys Law, activity of a component, Gibbs Duhem equation, nonideal solutions, regular solutions, quasichemical model of solution, activity and alternative standard states; reaction equilibrium in condensed system, Gibbs phase rule, binary systems involving compound formation, solubility of gases in metals, formation of oxide phases of variable composition; relation between chemical and electrical driving forces, Nernst equation, concentration and formation cells, Pourbaix diagrams; thermodynamics of Point Defects.
MSE201A	THERMODYNAMICS & PHASE EQUILIBRIA	3-1-0-0-11	I. Introduction, Thermodynamics terminology; 2. First law of thermodynamics and its applications; 3. Second law of thermodynamics and its consequences, Combined statement of first andsecond laws; 4. Statistical Statistical interpretation of entropy, entropy and Interpretations disorder; 5. Thermodynamic Auxiliary functions: Helmholtz free energy,functions Gibbs free energy, Chemical potential,Maxwell's relations, GibbsHelmholtz equations; 6. Third law of thermodynamics; 7. Phase equilibria in one component systems: single component system variation of Gibbs free energy with temperature and pressure, Clausius Clapeyron equation, PTdiagram; 8. Solutions Thermodynamics of solutions: Raoult's and Henry's Law, activity of a component, Regular solutions, Gibbs Duhem equation and its application, nonideal solutions, Sievert's Law,activity and altemative standard states, dilute solutions and interaction meters; 9. Reaction Equilibrium constant, Reaction equilibria for (a) homogeneous reactions consisting of gas mixtures, (b) heterogeneous reactions consisting of condensed phases and gas mixtures, Ellingham Diagram; I0. Phase rules Phase rules and its applications, Lever Rule; 11. Electrochemical cells Thermodynamics of electrochemical cells: Relation between chemical and electrical driving forces,

			Nemst equation, Concentration and formation cells, thermodynamics of aqueous solutions. Fundamentals of Free energy composition; 12. Free energy diagram for binary systems. Examples ofcomposition diagram common binary Free energy composition diagrams: Eutectic, Eutectoid, Peritectic etc; 13. Phase diagrams Study of some common phase diagrams, such asFeC, CuZn, AlCu, Fe0Si02 and evolution of equilibrium microstructure on cooling. **Course Reference**: I. Thermodynamics of Solids: Richard A. Swalin; 2. Introduction to Thermodynamics of Materials: David R. Gaskell; 3. Physical Chemistry of Metals: L. Darken and R.W. Gury; 4. Problems in Metallurgical Thermodynamics and Kinetics: G. S. Upadhyayaand R. K. Dube; 5. Phase Equilibria in Materials: S.P. Gupta; 6. Phase Transformation: Porter and Esterling.
MSE202A	RATE PROCESSES	3-1-0-0-11	1 Introduction to Fluid flow; 2. Introduction to heat transfer; 3. Introduction to mass transfer; 4. Mass transfer with Chemical reaction; 5. Introduction to Heterogeneous Reaction Kinetics; 6. Simultaneous Heat and Mass Transfer with Chemical reactions; 7. Introduction to Electrochemical Kinetics **Course Reference**: 1. Engineering in Process Metallurgy: R. Guthrie, Oxford Scientific Publications; 2. Transport Phenomena in Metallurgy: GH Geiger and DR Poirier; TMS publication; 3. Kinetic and metallurgical processes: Fathi Habashi; 4. Mass transport in solids and fluids: DS Wilkinson, Cambridge solid state science series.
MSE203A	STRUCTURE & CHARACTERIZATION OF MATERIALS	3-0-0-0-9	1. Introduction; 2. Crystalline State; 3. Noncrystalline state; 4. Microstructures; 5. Xray Diffraction; 6. Electron diffraction; 7. Optical microscopy; 8. Scanning electron microscope; 9. Transmission electron microscope; 10. Surface analysis technique **Course Reference**: 1. Elements of Xray diffraction, B.D. Cullity and S.R. Stocks, AddisonWeiley Publishing Co; 2. Introduction to solids, L.V. Azaroff, McGrawHill Book Company; 3. Elementary Crystallography by M.J. Buerger; 4. The structure of materials, S.M. Allen and E. L. Thomas, John Wiley and Sons, 1998; 5. Crystals and Crystal structures, R.J.D. Tilley, John Wiley and Sons, 2006; 6. Fundamentals of Materials Sciencethe microstructureproperty relationship using metals as model systems, E.J. Mittemeijer, Springer, 2010; 7. Micro structural Characterization of Materials D. Brandon and W.D. Kaplan, John Wiley and Sons, 2008

MSE204A	INTRODUCTION OF BIOMATERIALS	2-0-0-0-6	1. Introduction to Biomaterials; 2. Classification of biomaterials; 3. Structure Property correlation; 4. Processing and properties of biocompatible materials; 5. Surface engineering & case studies. Biomaterial Science: An introduction to Materials in Medicine, Edited by Ratner, Hoffman, Schoen and Lemons, Second Edition: Elsevier Academic Press, 2004. Biological Performance of Materials: Fundamentals of Biocompatibility, Janathan Black, Marcel Dekker, Inc., New York and Basel, 1981.
MSE210	METALLURGICAL KINETICS	3-1-0-0-4	Thermodynamics vs. kinetics, homogeneous and heterogeneous reactions; Chemical Reaction Controlrate equation, reaction rate constant, reaction order,nonelementary reactions; Solid State Diffusion Ficks Law, mechanism of diffusion, uphill diffusion, Kirkendall effect, steady and transient diffusion; External Mass Transfer fluid flow and its relevance to mass transfer, general 278 mass transport equation, concept of mass transfer coefficient, models of masstransfer film theory and Higbies penetration theory; Internal Mass Transfer Ordinary and Knudsen diffusion, Mass transfer with reaction; Adsorption physical adsorption vs. chemisorption, adsorption isotherms; Langmuir, BET, adsorption as the rate limiting step; gasification of C by CO2, dissolution of N2 in molten steel, porous solids, specific surface area and pore size distribution; Reactor Design batch vs. continuous reactors, ideal stirred tank and plug flow reactors,mass balance in ideal reactors, residence time distribution; models of industrial reactors; Electrochemical Kinetics concept of polarization, activation over potential, ButlerVolmer and Tafels equation, applications in electro deposition and corrosion,concentration over potential, limiting current; electrowinning and corrosion.
MSE250	MATERIALS CHARACTERIZATION	3-0-3-0-5	Chemical bonding, fundamentals of crystallography, reciprocal lattice, structures in metals, inorganic compounds, polymers, silicates and glasses, stereographic projections; Production, characterization, and interaction of Xrays with matter, Braggs Law and Laues equations, Ewalds construction, diffraction techniques and applications; Optical principles of microscopy resolution, magnification,depth of focus; electron diffraction, imaging (various contrasts), determination of crystal structure, burgers vector, electron beam specimen interactions andother applications of Transmission Electron Microscopy; Applications of Scanning Electron Microscopy and, Electron Probe Micro Analyser; Principles of Quantitative Microscopy: volume density, surface density, length density, numerical density,particle

			and grain size; Overview of other characterization techniques such as Auger electron spectroscopy, Scanning Tunneling Microscopy, Atomic Force Microscopy.
MSE300A	PROFESSIONAL & TECHNICAL COMMUNICATION	0-0-0-2-2	Importance of professional /technical communication Domains: Thesis/Report writing, Paper writing, Business letters, job letters, rsum, etc. Plagiarism: Importance, what is it and how to keep a check Projects/Assignments: Oral talks, Group discussions, Preparation of report, Presentation skills, and time management (on selecting contents, highlighting novelty, using visual aids and providing illustrations).
MSE301A	PHASE TRANSFORMATIONS	2-0-0-0-6	1. Introduction 2. Gibbs free energy change calculations 3. Interfaces 4. Nucleation 5. Growth 6. Transformation kinetics 7. Precipitation 8. Recrystallisation and grain growth 9. Martensitic Transformation 10. Isothermal and continuous cooling transformations 11. Spinodal decomposition 12. Solidification **Course Reference**: 1. Phase Transformations in Materials by R. C. Sharma, CBS Publishers, New Delhi; 2. Solid State Transformations by V. Raghavan, PrenticeHall of India, New Delhi
MSE302A	MECHANICAL BEHAVIOUR OF MATERIALS	3-0-0-0-9	1. Elasticity 2. Plasticity 3. Dislocations 4. Applications **Course Reference**: 1. Mechanical Behaviour of Materials, M.A. Meyers and K.K. Chawla; 2. Introduction to Dislocations, Hull and BaconReference Material; 3. Mechanical Metallurgy, G.E. Dieter; 4. Mechanical Behavior of Materials, Courtney; 5. Theory of Elasticity, Timoshenko; 6. An Introduction to Mechanics of Solids, S.H. Crandall and N.C. Dahl; 7. Deformation and Fracture Mechanics, R.W. Hertzberg; 8. Mechanical Testing, Metals Handbook; 9. Recrystallization and Related Annealing Phenomena, F.J. Humphreys.
MSE303A	ELECTRONIC & MAGNETIC PROPERTIES OF MATERIALS	3-0-0-0-9	1.Introduction to electronic structure 2. Electronic structure in crystalline materials 3. Electron Dynamics 4. Semiconductors 5. Ionic conductors 6. Dielectric materials 7. Magnetic materials 8. Optical materials **Course Reference**: 1. Electronic Properties of Materials: An Introduction for Engineers, Rolf E. Hummel, Springer Verlag, 1985; 2. Physical Properties of Semiconductors, Charles M. Wolfe, Nick Holonyak and Gregory E. Stillman, Prentice Hall, 1989; 3. Solid State Physics, Neil W. Ashcroft and N. David Mermin, Sauders College, Philadelphia, USA, 1976; 4. Advanced Theory of Semiconductor Devices, Karl Hess, Prentice Hall, 1988; 5. Advanced Semiconductor Fundamentals,

			Robert F. Pierret as part of Modular Series on Solid State Devices Vol; 6, Addison Wesley, 19896. Introduction to Solid State Physics, Charles Kittel, John Wiley & Sons 1991; 7. Electrical Properties of Materials, L. Solymar and D. Walsh, Oxford University press, 1998; 8. Physics of Solids, C. A. Wert and R.M. Thomson, McGrawHill Book Company, 1970 or later; 9. Physics of Semiconductor Devices by JP Colinge and C. A. Colinge, Kluwer Academic Pub. 2002; 10. Electronic Properties of Materials by R. E. Hummel, Springer, 2011.
MSE304A	PRINCIPLES OF METAL EXTRACTION & REFINING	2-0-0-0-6	1. Thermodynamics and Kinetics in metals extraction and refining 2. Principles of Mineral Beneficiation 3. Principles of Pyrometallurgy 4. Principles of Electrometallurgy 5. Principles of Hydrometallurgy 6. General issues related to metal extraction 7. Refining of Metals **Course Reference**: 1. DR Gaskel: An Introduction to Metallurgical Thermodynamics, McMillan Publishing Co., 1992; 2. Barry Willis: Mineral Processing Technology, Elsevier; 3. T.A. Engh: Principles of metal refining, Oxford Scientific Publications;1992; 4. JJ More: Chemical Metallurgy, Butterworth, 1990; 5. Terkel Rosenqvist: Principles of Extractive Metallurgy, 2nd Edition, Tapiar Academic Press
MSE305A	MATERIALS PROCESSING	2-0-0-0-6	1. Solidification Processing 2. Mechanical Working 3. Metal and Ceramic Powder Processing 4. ThinFilm and Coating Techniques **Course Reference**: 1. R.W. Heine, C.R. Loper, and P.C. Rosenthal, Principles of Metal Casting, 2nd ed., 1967; 2. A. Upadhyaya, G.S. Upadhyaya: Powder Metallurgy Science, Technology and Materials (2011); 3. Donald Leonard Smith; Thinfilm deposition: principles and practice; McGraw Hill; 4. J.N. Harris, Mechanical Working of Metals Theory & Practice, Pergamon Press, Exeter, UK, 1983.
MSE310	MECHANICAL BEHAVIOUR OF MATERIALS	3-1-0-0-5	Stress tensor and stress transformation equations, Principal stresses; Strain tensor and strain transformation equations; Isotropic and anisotropic elasticity,elastic strain energy; Yield criteria and constitutive relationships; Work hardening,plastic instability and its significance; Crystallographic aspects of plastic deformation; Dislocation theory edge, screw and mixed dislocations, resistance to dislocation motion and elastic properties of dislocations, dislocation interactions, multiplication and dissociation; Strengthening mechanisms; Creep characteristics of creep curve and steadystate creep, mechanisms and creep mechanism maps,creep under complex stressstates, prediction of long time properties;

			Fracture toughness and fatigue Griffiths crack theory, energy release rate analysis,modes of loading, stress analysis of cracks, fracture toughness, Low and Highcyclefatigue, Fatigue crack initiation and propagation, structural aspects offatigue, fatigue under complex stress states, environmental assisted crackingand fatigue; Some case studies related to design.
MSE311A	PHYSICAL METALLURGY LABORATORY	0-0-3-0-3	1. Metallographic specimen preparation 2. Optical microscopy of illustrative Ferrous samples 3. Optical microscopy of NonFerrous samples 4. Optical microscopy of Ceramic samples: Colour metallography and phase contrast microscopy of nonmetallic materials 5. Quantitative metallography and image analysis 6. Xray powder diffraction in materials analysis 7. Study of nucleation and growth in eutectoid steel 8. Carburization of Steel and Hardenability of steel 9. Recovery and Recrystallisation 10. Thermal analysis using DSC to study phase transformations 11. Bubble raft experiments 12. Stereographic projections
MSE312A	FUNCTIONAL MATERIALS LABORATORY	0-0-3-0-3	1. Ionic conductivity Conductivity measurement as a function of temperature for different samples; 2.Dielectric and ferroelectric/piezoelectric materials Measurement of dielectric constant Hysteresis loop; 3.Optical behavior of Liquid Crystals Measure response to applied field Measure the transmittance Measure threshold voltage; 4.Fabrication of organic light emitting diodes Partial fabrication of organic polymer light emitting diodes Characterization of an OLED; 5. Magnetic materials Magnetoresistance MH curves; 6. Semiconductor characterization Semiconductors resistivity Hall measurement Bandgap measurement; 7&8. Solar cell fabrication and characterization Fabrication of organic photovoltaic cells (PV) cells Characterization of solar cells; 9. Processing of biomaterials Fabricate biomaterials using (i) compression molding (for entire component), and(ii) electrostatic spraying (for coatings); 10. Tribology of biocoatings Tribology of two samples: (i) polymer with modifier (ii) polymer without modifier for comparison purpose. Comparison with metallic substrates (demo); 11. Biomimetics/ Surface modification. Effect of surface energy on wetting of surfaces Samples prepared by the students measuring the contact angle. Role of surface roughness/ chemistry on affecting the wettability of surface; 12. Effect of surface modification on Bacteria/ Cell growth Effect of surface modification/ functionalization characterized by comparing cell growth/ proliferation on treated versus pristine surfaces. One or more of the following will be performed by

			students to learn cell response:(i) Role of surface chemistry (hydrophobic/ hydrophilic and hydrophobic/ hydrophilic + modifier) (ii) Role of surface roughness
MSE313A	MECHANICAL BEHAVIOUR LABORATORY	0-0-3-0-3	1.Determination of tensile properties of different classes of materials; 2. Principles of Hardness Testing: comparison of different hardness measurement techniques; 3. Impact Testing of Materials: Charpy Impact Test; 4. Creep Testing of Materials; 5. Fatigue Testing; 6. Strain Ageing and Yield Point Phenomenon; 7. Observation of dislocations by using the etch pitting technique; 8. Effect of Work Hardening on Tensile Properties of Metals; 9. Plastic Anisotropy; 10. Project.
MSE314A	PROCESS ENGINEERING LABORATORY	0-0-3-0-3	1.Measurement techniques; 2. Laminar fluid flow; 3. Macroscopic energy balance (Bernoulli's equation); 4. Steady and unsteady conduction heat transfer; 5. Convective heat transfer 6. Radiation, heat transfer; 7. Mass transfer; 8. Thermodynamics; 9. Kinetics; 10. Mineral processing; 11. Hydrometallurgy-I 12. Hydrometallurgy-II; 13. Process metallurgy-I 14. Processing metallurgy-II;15. Electrochemistry.
MSE315A	MANUFACTURING PROCESSES LABORATORY	0-0-3-0-3	1. Deformation Behavior of Metals during Rolling and study of the associated microstructural changes; 2. Fluidity Measurement during Casting; 3. Permanent mold casting and casting defect evaluation; 4. Effect of MMAW and MIG Welding on the Microstructure and HAZ in Steels; 5. TIG and OAW Welding of Aluminium Alloys; 6. To Study Various Characteristics of Metal Powders and Evaluate the effect of particle size and shape on the green density, apparent density and green strength of cold compacted powders; 7.Conventional and Microwave Sintering of Particulate Compacts; 8.PM Design of Engineering Components (CDBased Design Expt); 9. Structural NanoMaterials through ECAP; 10. Spray Forming of Alloys and MMCs; 11. Micro Extrusion of Alloys; 12. Injection molding of thermo plastic polymers (e.g. PE, PP); 13. 3 Dimensional Printing (3DP) of designed structures; 14. Thin film deposition using evaporation technique
MSE320	PRINCIPLES OF METAL EXTRACTION AND REFINING	3-1-0-0-4	History and importance of metal extraction; Introduction of mineral dressing: Communition, Tabling, Jigging and flotation; Metallurgical fuels and the energy scenario; Pyro metallurgical operations roasting, agglomeration, smelting, refining and secondary refining; Principles of Hydro Metallurgy; Principles of Electro Metallurgy Aqueous solution and fused salts; Flow sheet design of importantnon ferrous metals based on materials and heat balance.

MSE330	PHASE EQUILIBRIA IN MATERIALS	3-1-0-0-5	Phase rule, lever rule and Free energy of phase mixtures; Binary isomorphous systems Equilibrium solidification, nonequilibrium solidification, dendritic growth, coring, CuNi alloys and Zone refining; Binary Eutectic and Peritectic Systems solidification of eutectic, hypoeutectic, and hypereutectic alloys;solidification of peritectic, hypoperitectic, and hyperperitectic alloys;morphologies of eutectic systems, Binary Monotectic and Syntectic Systems;Stability of regular solution and miscibility gas, intrinsic stability of solutionand spinodal; Hume Rothery rules and intermediate phases e.g., laves, sigma,electron compounds; Binary eutectoid, peritectoid, metatectic and monotectic systems; Ironcarbon phase diagram and micro structures of plain carbon steeland cast iron: nonequilibrium structures; Binary ceramics systems: SiO2AbOa,NiOMnO, etc.; Ternary phase diagrams Gibbs triangle, isothermal and vertical sections, polythermal projections, two phase equilibrium, concept of tie lines,rules for construction of tie lines, three phase equilibrium, concept of tietriangle,four phase equilibria; Multi component alloy systems: Stainless steels, high speed steels, Hadfield steels, super alloys, light metal alloys, refractory systems, (AbOaSiO2MgO) , sialanes.
MSE331	PROCESS METALLURGY LAB.	0-0-3-0-2	Laboratory techniques of temperature and flow rate measurement and calibration: Experiments on Mineral Engineering, Metallurgical Thermodynamics and Kinetics, Fuels and Furnaces, Iron making, steelmaking, pyro, hydro, electrometallurgy in extraction of nonferrous metals and metallurgical analysis.
MSE340	PHASE TRANSFORMATIONS IN MATERIALS	3-0-0-0-4	Thermodynamic order of transformations; Theory of nucleation Kinetics of homogeneous, transient and heterogeneous nucleation; Theory of Thermally Activated Growth: Interface controlled growth, Diffusion controlled growth, Interface instability and Widmanstatten growth, Eutectoid growth, Discontinuous precipitation, Massive transformation; Transformation Kinetics Johnson Mehlequation, Avrami model, Transformation kinetics in diffusion controlled transformations, Isothermal and continuous cooling transformation diagrams; Precipitation and Particle Coarsening; Kinetics of recrystallization, Theory of grain growth, Effect of second phase particles; Martensitic transformation Nature of martensitic transformations, Bain distortion, Nucleation, and growth of martensite, Athermal, isothermal and burst transformations, Thermoeleastic martensitie; Spinodal Decomposition Diffusion equation in spinodal region,Effect of gradient energy and

			elastic strain energy; Solidification Nature andgrowth of solidliquid interfaces, Rapid solidification, Glass transition, metallic glasses; Heat Treatment IT and CCT Diagrams in steels, quench hardening and tempering of martensite, hardenability of steels, surface hardening processes,tool steels and their heat treatments, heat treatment of cast irons, heat treatment of Nibase super alloys and Ti alloys, Thermo mechanical treatments.
MSE349A	UNDER GRADUATE PROJECT I	0-0-2-0-4	UG PROJECT (UGPI)
MSE350	IRON & STEEL MAKING	3-1-0-0-4	Refractories for iron and steel; Design and profile of an iron blast furnace andits auxiliaries; Performance evaluation of bast furnace Iron ore reduction, fuelrate calculations, BF aerodynamics and hot metal quality control; Energy and materials balance calculations in steel making processes; Physical chemistry of steel making and secondary steel making deoxidation, ladle and tundish metallurgy, ingot and continuous casting of steel; Emerging trends in iron and steel making.
MSE370	FUNDAMENTALS OF MATERIALS PROCESSING	3-0-0-0-4	Overview of various processing methods for materials; micro structural evolution during solidification and effect of cooling rate on cast microstructures, micro and macro segregation in alloys, directional solidification, rapid solidification; Elements of casting mold design solidification shrinkage and its role in riserdesign, fluid flow fundamentals and metal fluidity, elements of mold design;Fundamentals of deformation processing State of stress during various metal working operations, friction and its role in bulk metal forming operations, microstructural evolution during deformation processing, workability of metals, superplastic forming; Metal flow and aspects of design during bulk forming operations, elementary load calculations during various bulk metal working operations; Sheet metal forming State of stress during sheet metal forming processes, forming limit diagram, enhancement of sheet metal formability; Fundamentals of powder processing Basics of metal and ceramic powder productions and characterization, design aspects during powder consolidation; solid and liquid state sintering, driving force and mechanism of si ntering ,selection of sintering atmosphere for different systems, characterization of sintered products, full density processing.
MSE390	INDUSTRIAL TOUR	0-0-0-0-0	Visit to industries in and around Kanpur or elsewhere primarily of interest to Materials and Metallurgical Engineering.
MSE398A	UNDER GRADUATE	0-0-0-0-9	UP PROJECT (UGPII)

	PROJECT II		
MSE410	ELECTRONIC & MAGNETIC PROPERTIES OF MATERIALS	3-0-0-0-4	DC conductivity of metals, Hall effect and magneto resistance, AC conductivity of metals, thermal conductivity and specific heat of metals, Thermopower of metals; Review of quantum mechanics and free electron theory, failures of free electron theory and introduction to the role of lattice; Review of reciprocal lattice,Brilouin zone, Free electron band diagrams, potential in a crystal, electron dynamics and concept of holes, conductivity in relation to band structure, band structures of metals and semiconductors; empirical estimates of conductivity in metals and alloys; Semiconductors band diagrams, direct and indirect bandgap, applications of semiconductors; Degenerate and non degenerate semiconductors, intrinsic and extrinsic semiconductors, determination of dopant levels and mobility measurements; Ionic conduction review of defect equilibrium and diffusion mechanisms, theory of ionic conduction, conduction in glasses,effect of stoichiometric and extrinsic defects on conduction, applications insensors and batteries; Dielectric Materials Dielectric constant and polarization,linear dielectric materials, capacitors and insulators, polarization mechanisms,nonlinear dielectrics pyro, piezo and ferroelectric properties, hysterisis andferroelectric domains and applications; Optical Materials electronhole recombination, solidstate LEDs, lasers and IR detectors, band gap engineering;Light interaction with materials transparency, translucency and opacity, refraction and refractive index, reflection, absorption and transmission; Magnetic field,flux density, susceptibility and permeability; Orbital and spin, permanent magnetic moment of atoms, diamagnetism, paramagnetism and Pauli paramagnetism,ferro, antiferro and ferri magnetism, Fe, Co and Ni and alloy additions, ferrites, magnetic hysterisis, soft and hard magnet materials.
MSE415	PHYSICAL METALLURGY LAB	0-0-3-0-2	Laboratory techniques for studying phase transformations in materials, recrystallization and grain growth, eutectoid transformations in steels, hardenability, tempering of martensite; resistivity of metals, conductivity of semiconductors, conduction in ionic solids, dielectric measurements in BaTiO3, reflection, absorption and transmission measurement on various metals.
MSE425	PROCESS PLANT DESIGN FOR METT. ENGG. OPERATIONS	3-0-0--4	Identification of process flow sheet: Preliminary estimate of resources and facilities: Materials and energy balance, detailed plant flow sheet: Equipment selection and specification, economic

			selection and specification: environmental impact analysis: Report presentation, case studies of typical metallurgical plant operation.
MSE425A	PROCESS PLANT DESIGN FOR METT. ENGG. OPERATIONS	3-0-0-0-9	Identification of process flow sheet: Preliminary estimate of resources and facilities: Materials and energy balance, detailed plant flow sheet: Equipment selection and specification, economic selection and specification: Environmental impact analysis: Report presentation, case studies of typical metallurgical plant operation.
MSE449A	UNDER GRADUATE PROJECT IV	0-0-0-0-9	UG PROJECT (UGPIV)
MSE467	MATERIALS FOR SEMICONDUCTOR INDUSTRY	3-0-0--4	Semiconductor fundamentals, band structure, indirect and direct band gap, optical properties, carrier statistics, semiconductor material purification and crystal growth, epitaxy, CVD and MBE, PN Junction, Schottky and MaS device structures, specific material requirements, Doping by implantation and diffusion, dielectric and insulators, ohmic and barrier contacts, band edge behaviour, empirical rule, alloy design.
MSE467A	MATERIALS FOR SEMICONDUCTOR INDUSTRY	3-0-0--9	Semiconductor fundamentals, band structure, indirect and direct band gap, optical properties, carrier statistics, semiconductor material purification and crystal growth, epitaxy, CVD and MBE, PN Junction, Schottky and MaS device structures, specific material requirements, Doping by implantation and diffusion, dielectric and insulators, ohmic and barrier contacts, band edge behaviour, empirical rule, alloy design.
MSE480	MATERIALS DEGRADATION & ITS PREVENTION	2-0-0-0-2	Types of processes leading to degradation of materials, viz Oxidation Corrosion,Wear, Creep and fatigue review of basics of thermodynamics and kinetics relatedto oxidation and corrosion studies, Pourbaix diagram, Polarization, Mixedpotential theory, Passivity Characteristics of passivation ; Various types of degradation: atmospheric galvanic, intergranular, dealloying, crevice and pitting corrosion, microbiological, stress corrosion cracking, hydrogen damage, radiation damage; Oxidation and hot corrosion of materals at high temperatures; Wearof materials, analytical models of wear; Prevention of meaterials degradation alloying, environment conditioning design modification cathodic and anodic protection, metallic coating inorganic coating organic coating, inhibitors and passivators wear resistant materials structural modifications, wear resistant coatings.
MSE497A	UNDER GRADUATE PROJECT III	3-0-0-0-9	UG PROJECT (UGPIII)
MSE498	PROJECT I	0-0-4-0-2	PROJECT I
MSE499	PROJECT II	0-0-10-0-5	PROJECT II

MSE603	NONEQUILIBRIUM PROCESSING OF MATERIALS	3-0-0-0-4	Introduction to nonequilibrium processing Thermodynamics and kinetics of metastable phase formation; Rapid solidification: Undercooling. Phase diagram metastable states, Methods of rapid solidification, Mienrostructure formation by rapid solidification, Application for rapid solidification ; Mechanical alloying: Process of mechanical alloying, Mechanism of alloying Energy criteria formechanical alloying, Synthesis of nonequilibrium phases, Application of mechanical alloying, Metallic glass : Understanding of glass formation, thermal stability andglass forming ability, structure of metallic glass, crystallization behavior,properties of metallic glass, application, Special nonequilibrium processing and phase transformations
MSE604	SCIENCE AND TECHNOLOGY OF THIN FILMS AND DEVICE FABRICATION	3-0-0-0-4	1. Introduction Introduction to device processing steps, examples of various devices (with emphasis on solar cellsand MOSFETs) Need for miniaturization Thin Film Deposition; 2. Basics of thin film Brief review of kinetic theorygrowth Adsorption and desorption; 3. Film growth: nucletion and growth kinetics Epitaxy Thin film growth control. PVD Processes Evaporation (Thermal and ebeam) Principles of glow discharge and various sputtering processes; 4. Chemical Growth Fundamentals of CVD growth Processes of Modern variants: MOCVD, PECVD and ALD Spin Coating; 5. Basic Thin Film Thickness measurement Characterization Phase analysis, Optical analysis Morphology analysis, Device Fabrication; 6. Substrate seiection Selection of substrates and preparation, Single crystal growth (Silicon). Role of substrate surface and contaminants Physical and chemical methods of substrate surface preparation; 7. Pattern fabrication Concepts of lithography Photoresists (Negative, Positive etc) Exposure Development of Masking Variants of lithography with emphasis on Photo and ebeam Precautionary steps; 8. Material Removal Wet (Chemical) and dry (Plasma, RIE etc.) etching; 9. Jon implantation, Doping and ion Implantation Doping, oxidation and Diffusion control of composition in devices and heat treatment Oxidation and heat treatment 10. Metallization and Adhesion and morphology issues Interconnects Introduction to electromigration visavis metallization: Impact on device performance and methods of prevention. Process Integration Example of process integration for a particular kind offor a particular case device e.g. Si Solar Cell, MOSFET, 111V solar cell devices (take the case of adevice) VLSI Fabrication: S.K. Gandhi Si Processing (Volume I and II) Lou and Mayer

			Introduction to Microfabrication by Sami Fransilla (Wiley) Fundamentals of Microfabrication: The Science of Miniaturization by Marc Madou (CRC Press) Thin film deposition by Donald Smith (Me Graw Hill) Materials science of thin films by Milton Ohring (Academic Press) Pulsed Laser deposition of thin films by Chrisey and Hubler (Wiley Interscience)
MSE604A	SCIENCE AND TECHNOLOGY OF THIN FILMS AND DEVICE FABRICATION	3-0-0-0-9	1. Introduction to device processing steps, Examples of various devices (with emphasis on solar cellsand MOSFETs) Need for miniaturization Thin Film Deposition; 2. Basics of thin film Brief review of kinetic theorygrowth Adsorption and desorption; 3 Film growth: nucletion and growth kinetics Epitaxy Thin film growth control. PVD Processes Evaporation (Thermal and ebeam) Principles of glow discharge and various sputtering processes; 4. Chemical Growth Fundamentals of CVD growth Processes 4 Modern variants: MOCVD, PECVD and ALD Spin Coating; 5. Basic Thin Film Thickness measurement, Characterization Phase analysis, Optical analysis Morphology analysis Device Fabrication; 6. Substrate seiection Selection of substratesand preparation, Single crystal growth (Silicon). Role of substrate surface and contaminants Physical and chemical methods of substrate surface preparation; 7. Pattern fabrication Concepts of lithography Photoresists (Negative, Positive etc) Exposure Development Masking Variants of lithography with emphasis on Photo and ebeam Precautionary steps; 8. Material Removal Wet (Chemical) and dry (Plasma, RIE etc.) etching; 9. Jon implantation, Doping and ion Implantation Doping, oxidation Diffusion control of composition in devices and heat treatment Oxidation and heat treatment; 10. Metallization and Adhesion and morphology issues Interconnects Introduction to electro migration visavis metallization: Impact on device performance and methods of prevention; 11. Process Integration Example of process integration for a particular kind off or a particular case device e.g. Si Solar Cell, MOSFET, 111V solar cell devices (take the case of adevice) VLSI Fabrication: S.K. Gandhi Si Processing (Volume I and II) Lou and Mayer Introduction to Microfabrication by Sami Fransilla (Wiley) Fundamentals of Microfabrication: The Science of Miniaturization by Marc Madou (CRC Press) Thin film deposition by Donald Smith (Me Graw Hill) Materials science of thin films by Milton Ohring (Academic Press) Pulsed Laser deposition of thin films by Chrisey and Hubler (Wiley Interscience)
MSE605	SURFACE PHENOMENA	3-0-0-0-4	Surface Chemistry/Interaction (surface charge,

	AND CHARACTERIZATION		dipoles, energies, interfacial chemical reactions), Surface Phonons/Plasmons (Quantisation of plasma, light and, sound, Brillioun Zones), Elastic/Inelastic scattering, Electromagnetic scattering (Compton, Rayleigh, Rutherford, Thomson), Crystal structure and Reciprocal Lattice, Brillouim Zone, Surface Diffusion (Fick's law, intergraular/amorphous layer formation),Surface Energy/Young's Equation (Capillary/surface tension in fluids), Surface Sensitive Properties: Pussivation/Adsorption (Forces/Chemical bonds on surface), Interfacial wetting (formationof interfaces, contact angle in wetting surfaces), Density functional theory of atomic equilibrium, Case Studies: FeB49 system, and Al2O3 carbon nanotube, Surface Modification/Unctionalization Nanostructures: Self Assembly (adding molecules to surface), Distribution of phase : Voronoi and Dirichlet Tessellation, Molecular Sieves (Molecular filters : purification of gases/chemicals etc). **Course Reference**: 1. Materials Science and Tedmology. Ed. R.W. Kahn, P. Hassen, E.J. Kramer, Vol. 2n/2b, Wiley YCII (2005); 2. Physics of Atoms and Molecules. B.H. Bransden, and C.J. Joachain, Longman (1996); 3. Surface Analysis Methods in Materials Science, D. J; Connors, B.A. Sexlon, and R. St. C. Smart, Springer (2003); 4. The Physics and Chemistry of Materials, J. I. (Gersten, F. W. Smith. Wiley (2001); 5. Elementary-Solid State Physics. M. A, Omar, AddisonWesley (2001); 6. Course materials wlll be supplememed with hundouts, and journal publications.
MSE605A	SURFACE PHENOMENA AND CHARACTERIZATION	3-0-0-0-9	Surface Chemistry/Interaction (surface charge, dipoles, energies, interfacial chemical reactions), Surface Phonons/Plasmons (Quantisation of plasma, light and, sound, Brillioun Zones), Elastic/Inelastic scattering, Electromagnetic scattering (Compton, Rayleigh, Rutherford, Thomson), Crystal structure and Reciprocal Lattice, Brillouim Zone, Surface Diffusion (Fick's law, intergraular/amorphous layer formation), Surface Energy/Young's Equation (Capillary/surface tension in fluids), Surface Sensitive Properties: Pussivation/Adsorption (Forces/Chemical bonds on surface), Interfacial wetting (formationof interfaces, contact angle in wetting surfaces), Density functional theory of atomic equilibrium, Case Studies: FeB49 system, and Al2O3 carbon nanotube, Surface Modification/Unctionalization Nanostructures: Self Assembly (adding molecules to surface), Distribution of phase : Voronoi and Dirichlet

			Tessellation, Molecular Sieves (Molecular filters : purification of gases/chemicals etc). **Course Reference**: 1. Materials Science and Tedmology. Ed. R.W. Kahn, P. Hassen, E.J. Kramer, Vol. 2n/2b, Wiley YCII (2005); 2. Physics of Atoms and Molecules. B.H. Bransden, and C.J. Joachain, Longman (1996); 3. Surface Analysis Methods in Materials Science, D. J. Connors, B.A. Sexlon, and R. St. C. Smart, Springer (2003); 4. The Physics and Chemistry of Materials, J. I. (Gersten, F. W. Smith. Wiley (2001); 5. Elementary- Solid State Physics. M. A, Omar, AddisonWesley {2001); 6. Course materials wlll be supplememed with hundouts, and journal publications.
MSE607	COMPUTING APPLICATIONS IN METALLURGY	3-1-0--5	Fortran fundamentals: Applications of regression analysis and curve fitting techniques, computer calculations of phase diagrams: Numerical of partial differential equations pertinent to heat, mass and momentum transfer: Computer applications in solidification, potential energy diagrams and experiment inmetallurgy.
MSE611A	CORROSION AND OXIDATION OF METALS AND ALLOYS	3-0-0-0-9	Introduction to Corrosion and Oxidation; Review of basics of Thermodynamics and Kineticsrelated to corrosion and oxidation; Pourbaix diagram and its relation to aqueous corrosion; Basic electrochemistry related to corrosion and advanced theory of electrochemical kinetics and corrosion; Polarization; Mixed potential theory; Passivity; Various types of corrosion: Galvanic,Intergranular, Crevice, Pitting, Dealloying, Erosion corrosion, Stress corrosion and hydrogen embrittlement; Corrosion protection mechanism and methods; Oxidation and hot corrosion at high temperatures; Interaction between metals and different gases and Ellingham diagram; Wagner laws of oxidation; Oxide structure and oxidation; Oxidation protection mechanisms and methods; Coatings: Different types of Coatings, Coating methods and characteristics of Coating. **Course Reference**: 1. Corrosion: L.L. Shreir, NewnesButterworths (London), 1976; 2. Corrosion and Corrosion Control: HH Uhlig and W. Revie, Wiley, New York, 2007; 3. Corrosion Science and Technology. David Talbot, James Talbot, CRC Press, 1998; 4. Corrosion Engineering by Mars. G. Fontana, Third ed. , TMH; 5.Environmental Degradation of Metals: UK Chatterjee, S K Bose and S K Roy, MarcelDekker, 2001; 6.Oxidation of Metals and Alloys: 0. Kubaschewski and B.E. Hopkins, Butterworths(London) 1967; 7.High Temperature Oxidation of Metals: P. Kofstad, John Wiley & Sons, Inc, 1966; 8.Materials Degradation and Its Control by Surface Engineering: A. W.

			Batchelor, L.N.Lam and M Chandrasekharan, Imperial College Press, 2002
MSE613	ELECTROCHEMICAL TECHNOLOGY IN MATERIALS PROCESSING	3-0-0--4	Thermodynamic of electrolyte, electrochemical potential, conduction of ions insolution, overpotential, absorption, phase formation: Economics of an electrolytic process, principles of cell design, Electrochemical technology: Elactowinning, electro refining and metal electroforming, electrochemical machining, electroplating, anodizing, pickling, electrophoretic painting, electrochemical treatment of minerals, batteries and fuel cells, water treatment and environmental protection.
MSE613A	ELECTROCHEMICAL TECHNOLOGY IN MATERIALS PROCESSING	3-0-0-0-9	Thermodynamic of electrolyte, electrochemical potential, conduction of ions insolution, overpotential, absorption, phase formation: Economics of an electrolytic process, principles of cell design, Electrochemical technology: Elactrowinning, electrorefining and metal electroforming, electrochemical machining, electroplating, anodizing, pickling, electrophoretic painting, electrochemical treatment of minerals, batteries and fuel cells, water treatment and environmental protection.
MSE615	STRUCTURE AND CHARACTERIZATION OF MATERIALS	3-0-0-0-4	Basic crystallography and crystal structures (8 Lectures hour) Periodic patterns, Lattices, Motif, Unit cells, Crystal structure, Primitive and Non primitive cells, Symmetry elements and point group notations, Crystal systems and Bravais lattices, Crystallographic directions and planes, Miller indices and Weiss zone law, Streographic projections, Bonding in materials and atomic packing in metals, coordination number concepts, Covalent bonding, glasses and polymers, Crystal defects and their significance (12 Lectures hours)Point defects and their role in materials Processing, performance and failure , Ionically bonded structures: Pauling's rules and some examples, Point defects: thermodynamics, schottkey and Frenkel defect, KrogerVink notation, defect interactions, Dislocations, burgers vector, types of dislocations , Dislocation movement, slip systems, energetics of dislocations and their interactions, Planar defects: stacking faults, grain boundaries (low angle and high angle), antiphase **Course Reference**:1. Crystals and Crystal structures, R.J.D. Tilley, John Wiley and Sons, 2006; 2. Materials Science and Engineering W.D. Callister, Jr. Wiley India(P) Ltd., 2007; 3. Materials Science and Engineering, G.S. Upadhyaya and Anish Upadhyaya, Viva books, 2010; 4. Fundamentals of Materials Sciencethe microstructure property relationship using metals as model systems, E.J. Mittemeijer, Springer,

			2010; 5. Microstructural Characterization of Materials D. Brandon and W.D. Kaplan, John Wiley and Sons, 2008; 6. Science of Microscopy, P.W. Hawkes and J.C.H. Spence, Springer, 2007; 7. Scanning Electron Microscopy & XRay Microanalysis, J.Goldstein et.al, Springer, 2003; 8. Transmission Electron Microscopy B.D.Williams & C.B.Carter, Springer, 2009;9. Surface Analysis methods in materials science, Editors: D.J.O;Connor, B.A. Sextton, R.St. C. Smart, Springer, 2003;10. Materials Characterisation Techniques, S. Zhang, Lin Li and Ashok Kumar, CRC Press, 2009
MSE615A	STRUCTURE AND CHARACTERIZATION OF MATERIALS	3-0-0-0-9	Basic crystallography and crystal structures (8 Lectures hour) Periodic patterns, Lattices, Motif, Unit cells, Crystal structure, Primitive and Non primitive cells , Symmetry elements and point group notations, Crystal systems and Bravais lattices, Crystallographic directions and planes, Miller indices and Weiss zone law, Streographic projections, Bonding in materials and atomic packing in metals, coordination number concepts, Covalent bonding, glasses and polymers,Crystal defects and their significance (12 Lectures hours) Point defects and their role in materials Processing, performance and failure , Ionically bonded structures: Pauling's rules and some examples, Point defects: thermodynamics, schottkey and Frenkel defect, KrogerVink notation, defect interactions, Dislocations, burgers vector, types of dislocations, Dislocation movement, slip systems, energetics of dislocations and their interactions 2, Planar defects: stacking faults, grain boundaries (low angle and high angle), antiphase **Course Reference**:1. Crystals and Crystal structures, R.J.D. Tilley, John Wiley and Sons, 2006; 2. Materials Science and Engineering W.D. Callister, Jr. Wiley India(P) Ltd., 2007; 3. Materials Science and Engineering, G.S. Upadhyaya and Anish Upadhyaya, Viva books, 2010; 4. Fundamentals of Materials Sciencethe microstructureproperty relationship using metals as model systems, E.J. Mittemeijer, Springer, 2010; 5. Microstructural Characterization of Materials D. Brandon and W.D. Kaplan, John Wiley and Sons, 2008; 6. Science of Microscopy, P.W. Hawkes and J.C.H. Spence, Springer, 2007; 7. Scanning Electron Microscopy & XRay Microanalysis, J.Goldstein et.al, Springer, 2003; 8. Transmission Electron Microscopy B.D.Williams & C.B.Carter, Springer, 2009; 9. Surface Analysis methods in materials science, Editors: D.J.O;Connor, B.A. Sextton, R.St. C. Smart, Springer, 2003; 10. Materials Characterisation Techniques, S. Zhang,

			Lin Li and Ashok Kumar, CRC Press, 2009
MSE616	THERMODYNAMICS OF MATERIALS	3-0-0-0-4	1.Thermodynamic systems and variables: First, second and third laws of thermodynamics. Statistical interpretation of entropy; 2. Free energy functions and criteria for equilibrium. 3.Thermodynamics of solutions. Ideal and nonideal solutions, Partial and molar quantities; 4. Quasichemical model and regular solutions, Polynomial expressions for excess Gibbs energy of mixing for binary and higher order solutions; 5. Multicomponent dilute solutions and interaction parameters. Chemical reaction equilibrium, equilibrium constant; applications to materials and metallurgical systems; 6. Electrochemical systems, cell reactions and EMF, Formation and concentrations cells. 3 Phase rule and binary phase diagrams, Free energy composition diagrams 3 Phase equilibrium calculations 7. Introduction to ternary phase diagrams.
MSE616A	THERMODYNAMICS OF MATERIALS	3-0-0-0-9	1.Thermodynamic systems and variables: First, second and third laws of thermodynamics; Statistical interpretation of entropy; 2. Free energy functions and criteria for equilibrium; 3. Thermodynamics of solutions. Ideal and nonideal solutions, Partial and molar quantities; 4. Quasichemical model and regular solutions; 5. Polynomial expressions for excess Gibbs energy of mixing for binary and higher order solutions. Multicomponent dilute solutions and interaction parameters. Chemical reaction equilibrium, equilibrium constant; applications to materials and metallurgical systems. Electrochemical systems, cell reactions and EMF, Formation and concentrations cells. Phase rule and binary phase diagrams to Free energy composition diagrams 3Phase equilibrium calculations 5Introduction to ternary phase diagrams.
MSE617	MATHEMATICS AND COMPUTATIONAL METHODS	3-0-0-0-4	1.Introduction of functions, vectors, matrices; 2. Partial Differentiation (Total differentiation, Maximum and minimum: method of Lagrange multipliers, Change of variables: Legendre transformation, Differentiation of integral; Leibniz rule); 3. Multiple Integration (Change of variable: Jacobian, Surface and volume integrals); 4. Vectors (Geometry: Lines and planes, Directional derivative, gradients (fields, equipotential, grad, normal to surface, curl, div), Line integration (conservative fields, potential, exact differentiation), Green, Stokes, Div and Curl theorems; 5. Coordinate Transformation (Linear transform, Orthogonal transform, Eigenvalues: diagonalization of matrix); 6. Ordinary differential equations (Linear first order, Second order: constant coefficient and

			zero right hand side, Second order: constant coefficient and non zero right hand side); 7. Statistics. Introduction to random experiment, computing probability of an event
MSE617A	MATHEMATICS AND COMPUTATIONAL METHODS	3-0-0-0-9	1. Introduction of functions, vectors, matrices;2. Partial Differentiation (Total differentiation, Maximum and minimum: method of Lagrange multipliers, Change of variables: Legendre transformation, Differentiation of integral; Leibniz rule); 3. Multiple Integration (Change of variable: Jacobian, Surface and volume integrals); 4. Vectors (Geometry: Lines and planes, Directional derivative, gradients (fields, equipotential, grad, normal to surface, curl, div), Line integration (conservative fields, potential, exact differentiation), Green, Stokes, Div and Curl theorems; 5. Coordinate Transformation (Linear transform, Orthogonal transform, Eigenvalues: diagonalization of matrix); 6. Ordinary differential equations (Linear first order, Second order: constant coefficient and zero right hand side, Second order: constant coefficient and non zero right hand side); 7. Statisticsa. Introduction to random experiment, computing probability of an event
MSE621	XPS AND AES IN STUDY OF SURFACE AND THIN FILMS	3-0-0-0-4	Solid surfaces, their structure and composition: Importance of the surfaces/ Surfaces in different materials/ Structural imaging/ Composition of surface selvedges; Practical detection and spatial limits; Chemical tste information; Techniques to probe electronic structure at surfaces. Xray Photoelectron Spectroscopy Basics: Principles; Instrumentation; Vacuum systems, Xray sources, synchrotron radiation, electron energy analyzers; Spectral information, chemical shifts and interpretations; Quantification, depth profiling, imaging. XPS Applications: Catalysis; polyments and organic materials; corrosion, passivation and oxidation; superconductor; semiconductors; metallurgy/ tribology; thin films; Biomaterials, Case studies and lab visit/demo. Auger Electron Spectroscopy Basics: Principles; Instrumentation; Vacuum requirements, Electron sources, electron energy analyzers; Spectral information and interpretation; Quantification, depth profiling, imaging. **Course Reference**:1. Surface and Thin Film Analysis, Editors; G. Friedbachaer and H. Bubert, WileyVCH, 2011; 2. Encyclopedia of Materials Characterisation, C.R. Brundle, C.A. Evans and S. Wilson, ButterworthHennmann, 1992, Boston; 3. Introduction to Photoelectron spectoscopy P.K. Ghosh, John Wiley and Sons, WileyIntersicence, 1978, New York. 4. Surface Analysis Methods in Materials Science, D.J Connors, B.A. Sexton, and

			R. St. C. Smart, Springer (2003); 5. Photoelectron and Auger spectroscopy. Thomas A Carlson, Plenum, New York, 1975; 6. Topics in Current physics: Electron spectroscopy for surface analysis, Ed. H. Ibach, SpringerVerlag, Berlin, 1977; 7. Scanning Auger electron microscopy, Editors: M. PLrutton and Mohamed M. El Gomati, John Wiley & Sons, 2006; 8. Practial guide to surface science and spectroscopy. YipWah Chung, Academic Press, Boston, 2001.
MSE621A	XPS AND AES IN STUDY OF SURFACE AND THIN FILMS	3-0-0-0-9	Solid surfaces, their structure and composition: Importance of the surfaces/ Surfaces in different materials/ Structural imaging/ Composition of surface selvedges; Practical detection and spatial limits; Chemical tste information; Techniques to probe electronic structure at surfaces. Xray Photoelectron Spectroscopy Basics: Principles; Instrumentation; Vacuum systems, Xray sources, synchrotron radiation, electron energy analyzers; Spectral information, chemical shifts and interpretations; Quantification, depth profiling, imaging. XPS Applications: Catalysis; polyments and organic materials; corrosion, passivation and oxidation; superconductor; semiconductors; metallurgy/ tribology; thin films; Biomaterials, Case studies and lab visit/demo. Auger Electron Spectroscopy Basics: Principles; Instrumentation; Vacuum requirements, Electron sources, electron energy analyzers; Spectral information and interpretation; Quantification, depth profiling, imaging. **Course Reference**: 1. Surface and Thin Film Analysis, Editors; G. Friedbachaer and H. Bubert, WileyVCH, 2011; 2. Encyclopedia of Materials Characterisation, C.R. Brundle, C.A. Evans and S. Wilson, Butterworth Hennmann, 1992, Boston; 3. Introduction to Photoelectron spectoscopy P.K. Ghosh, John Wiley and Sons, WileyInter sicence, 1978, New York; 4. Surface Analysis Methods in Materials Science, D.J. ;Connors, B.A. Sexton, and R. St. C. Smart, Springer (2003); 5. Photoelectron and Auger spectroscopy. Thomas A Carlson, Plenum, New York, 1975; 6. Topics in Current physics: Electron spectroscopy for surface analysis, Ed. H. Ibach, SpringerVerlag, Berlin, 1977; 7. Scanning Auger electron microscopy, Editors: M. PLrutton and Mohamed M. El Gomati, John Wiley & Sons, 2006; 8. Practial guide to surface science and spectroscopy. YipWah Chung, Academic Press, Boston, 2001.
MSE626	HEAT AND MASS TRANSFER	3-1-0--5	Review of the basic concepts in Heat, Mass and Momentum transfer: Advanced topics in convective heat and heat transfer: Radiative heat transmission: Simultaneous heat and mass

			transfer: Selected topics in metallurgical engineering, Reaction kinetics.
MSE626A	TRANSPORT PHENOMENA	3-0-0-0-9	1. Fluid dynamics: Introduction to Transport phenomena in materials processing, Newton's law of viscosity, equation of continuity, Navier Stokes equations, Macroscopic mass and energy balance; Characteristics of industrial flows, Numerical problems on above topics of interest to metals and materials processing; 2. Heat transfer: Fundamentals of conduction heat transfer; Laws and equations; Steady and unsteady heat, conduction Numerical problems on conductive heat transfer, Fundamentals of convective heat transfer; free and forced convective heat transfer, Convective, heat transfer rate laws and heat transfer coefficient Problems on Convective heat transfer, Fundamentals of Radiation heat transfer and rate laws; view factors, Problems on Radiation heat transfer, Application of heat transfer in: Heat treatment, solidification, cooling of slabs, heat flow, through refractory walls etc; 3. Mass Transfer : Fundamentals of diffusion; rate laws, Uphill diffusion and Kirkendal's effect, steady and unsteady diffusion, Numerical problems on diffusion mass transfer, Fundamentals of convective mass transfer; free and forced convective mass transfer transfer, Convective mass transfer, rate laws and mass transfer coefficient, Problems on Convective mass transport, Application of mass transfer in: case hardening, doping of semi conductors, homogenization, oxidation, absorption/desorption of gases in liquid metals. **Course Reference**: 1. Transport phenomena: D. R. Geiger and G. H. Poirier; 2. Transport phenomena: D. R. Gaskel; 3. Engineering in process metallurgy: R. Guthrie; 4. Mass transport in solids and fluids: D. S. Wilkinson. **Other Recommended Reference books**:1. Diffusion in solids: P. G. Shewrnan; 2. Atom movements diffusion and mass transport in solids: J. Philibert; 3. Diffusion in solids: field theory, solidstate principles, and applications: M. E. Glicksman
MSE626N	TRANSPORT PHENOMENA	3-0-0-0-4	I. Fluid dynamics : Introduction to Transport phenomena in materials processing, Newton's law of viscosity, equation of continuity, Navier Stokes equations, Macroscopic mass and energy balance ; Characteristics of industrial flows, Numerical problems on above topics of interest to metals and materials processing; 2. Heat transfer: Fundamentals of conduction heat transfer; Laws and equations; Steady and unsteady heat, conduction Numerical problems on conductive heat

			transfer, Fundamentals of convective heat transfer; free and forced convective heat transfer, Convective, heat transfer rate laws and heat transfer coefficient Problems on Convective heat transfer, Fundamentals of Radiation heat transfer and rate laws; view factors, Problems on Radiation heat transfer, Application of heat transfer in: Heat treatment, solidification, cooling of slabs, heat flow, through refractory walls etc; 3. Mass Transfer : Fundamentals of diffusion; rate laws, Uphill diffusion and Kirkendal's effect, steady and unsteady diffusion, Numerical problems on diffusion mass transfer, Fundamentals of convective mass transfer; free and forced convective mass transfer transfer, Convective mass transfer, rate laws and mass transfer coefficient, Problems on Convective mass transport, Application of mass transfer in: case hardening, doping of semi conductors, homogenization, oxidation, absorption/desorption of gases in liquid metals. **Course Reference**: 1. Transport phenomena: D. R. Geiger and G. H. Poirier; 2. Transport phenomena: D. R. Gaskel; 3. Engineering in process metallurgy: R. Guthrie; 4. Mass transport in solids and fluids: D. S. Wilkinson. **Recommended other reference books**:1. Diffusion in solids: P. G. Shewrnan; 2. Atom movements diffusion and mass transport in solids: J. Philibert; 3. Diffusion in solids: field theory, solidstate principles, and applications: M. E. Glicksman
MSE628	ELECTRONIC DEVICES AND CHARACTERIZATION	3-0-0-0-4	Electronic Device related characteristics of a semiconductor material Review: n and p type semiconductors, wafers, carrier mobility, conductivity, equilibrium carrier statistics, generation recombination processes and carrier transport, traps and defect states (2) Characterization : (a) Doping density: Secondary Ion Mass Spectroscopy (SIMS) (0.75)(b) Resistivity: Fourpoint probe (0.75) (c) Charge carrier type, density, mobility: Hall effect (1)(d) Bandgap: UVVisible spectroscopy (0.75) (e) Absorption coefficient (0.5)2 Semiconductor semiconductor junction : (a) PN junction in thermal equilibrium, I-V characteristics: qualitative (3) (b) PN junctions I-V characteristics of an ideal device, origin of non idealities (4) (c) Diode variants: solar cell I-V with illumination and bias effect and PIN diode, LEOs (2.5) (d) Device measurement of a solarell (Light and dark I-V, R5 , Rsh, Efficiency) (0.5) (e) BJTs: Principle and device measurement (2)3 Metal Semiconductor junction : (a) Schottky and Ohmic contacts, thermionic emission,

			Tunnelling, Schottky diodes (2) (b) Contact resistance: Two terminal; Four terminal technique (0. 5) 5 (c) Barrier height: From 1V, CV, Photocurrent; comparison ofthree (1) (d) Capacitance Voltage measurements: DopingDensity and majority carrier density profiling (1) (e) Band offset for a semiconductor semiconductor junction using CV technique (0.5) 4 Metal insulator semiconductor junctions : (a) MOS capacitor, quantitative analysis of a flat band device, CV characteristics (4.5) (b) MOS capacitor: deviations from flat band conditions (2.5) (c) Oxide charges : fixed, mobile, trapped and interface trapped charges (1) (d) MOSFET (5) (e) FinFET MOSFET: Architecture for creating simple Boolean logic, memory Dopant density profiling using CV (already discussed in section 3 above) **Course Reference**: 1. Semiconductor Material and Device Characterization, Dieter K. Schroder, January 2006,WileyIEEE Press; 2. Metal Semiconductor Contacts (Electrical & Electronic Engineering Monographs), E. H.Rhoderick and R. H. Williams, Oxford University Press, USA; 2nd edition (September I,1988); 3. Electronic Structure of Metal Semiconductor Contacts, Winfried Monch (Nov 30,I990)Springer; I edition (November 30, I990); 4.Optical Techniques for SolidState Materials Characterization, Rohit P. Prasankumar and Antoinette J. Taylor, CRC Press; I edition (July 5, 201I); 5. Semiconductor Device Fundamentals by Robert F. Pierret, Addison Wesley; 2nd edition(April 12, I996); 6. Advanced Semiconductor Fundamentals (2nd Edition) by Robert F. Pierret, Prentice Hall; 2 edition (August 19, 2002); 7. Semiconductor Devices: Physics and Technology, Simon M. Sze, MingK wei Lee,Wiley; 3 edition (May I5 , 20I2).
MSE628A	ELECTRONIC DEVICES AND CHARACTERIZATION	3-0-0-0-9	Electronic Device related characteristics of a semiconductor material Review: n and p type semiconductors, wafers, carrier mobility, conductivity, equilibrium carrier statistics, generation recombination processes and carrier transport, traps and defect states {2}Characterization : {a} Doping density: Secondary Ion Mass Spectroscopy (SIMS) {0.75}{b} Resistivity: Fourpoint probe (0.75) (c) Charge carrier type, density, mobility: Hall effect (1)(d) Bandgap: UVVisible spectroscopy (0.75) (e) Absorption coefficient (0.5)2 Semiconductor semiconductor junction : (a) PN junction in thermal equilibrium, I-V characteristics: qualitative (3) (b) PN junctions I-V characteristics of an ideal device, origin of non idealities (4) (c) Diode variants: solar cell I-V with illumination and bias effect and PIN

			diode, LEOs (2.5) (d) Device measurement of a solar cell (Light and dark JV, R5 , Rsh, Efficiency) (0.5) (e) BJTs: Principle and device measurement (2)3 Metal Semiconductor junction : (a) Schottky and Ohmic contacts, thermionic emission, Tunnelling, Schottky diodes (2) (b) Contact resistance: Two terminal; Four terminal technique (0. 5) 5 (c) Barrier height: From 1V, CV, Photocurrent; comparison ofthree (1) (d) Capacitance Voltage measurements: Doping Density and majority carrier density profiling (1) (e) Band offset for a semiconductor semiconductor junction using CV technique (0.5) 4 Metal insulator semiconductor junctions : (a} MOS capacitor, quantitative analysis of a flat band device, CV characteristics (4.5) (b) MOS capacitor: deviations from flat band conditions (2.5) (c) Oxide charges : fixed, mobile, trapped and interface trapped charges (1) (d) MOSFET (5) (e) FinFET MOSFET: Architecture for creating simple Boolean logic, memory dopant density profiling using CV (already discussed in section 3 above). **Course Reference**: 1. Semiconductor Material and Device Characterization, Dieter K. Schroder, January 2006,WileyIEEE Press; 2. Metal Semiconductor Contacts (Electrical & Electronic Engineering Monographs), E. H.Rhoderick and R. H. Williams, Oxford University Press, USA; 2 edition (September I,1988); 3. Electronic Structure of Metal Semiconductor Contacts, Winfried Monch (Nov 30,I990)Springer; I edition (November 30, I990); 4. Optical Techniques for SolidState Materials Characterization, Rohit P. Prasankumar and Antoinette J. Taylor, CRC Press; I edition (July 5, 201I); 5. Semiconductor Device Fundamentals by Robert F. Pierret, Addison Wesley; 2nd edition(April 12, I 996); 6. Advanced Semiconductor Fundamentals (2nd Edition) by Robert F. Pierret, PrenticeHall; 2 edition (August 19, 2002); 7. Semiconductor Devices: Physics and Technology, Simon M. Sze, MingK wei Lee,Wiley; 3 edition (May I5 , 20I2)
MSE629A	PHYSICAL & MATHEMATICAL MODELLING OF STEELMAKING PROCESSES	3-0-0-0-9	Brief review of scientific fundamentals such as thermodynamics, kinetics and transport phenomena of relevance to steel making: Mathematical modeling techniques: Principles of physical modeling: Successful modeling examples including converter steel making, gas stirred ladles: Alloy addition kinetics, tundish operations and continuous casting.
MSE630	ADVANCES IN IRON AND STEEL MAKING	3-0-0--4	Recent trends in iron and steel making: Gassolid and slagmetal reaction: Spongeiron making: Continuous steel making: Continuous casting: Vacuum degassing and electro slag remelting:

			Advances in agglomeration, blast furnace and steel making, analysis of iron and steel making processes and reactors: Deoxidation and impurity control: Emphasis on application of physical chemistry and transport phenomena.
MSE631	ELECTROCERAMIC MATERIALS AND APPLICATIONS	3-0-0-0-4	Introduction, FCC packed structures (MgO, Ce02 etc), HCP packed structures (LiNb03 etc), Other structures such as Perovskite (BaTi03 etc) and Rutile structures, Defects in Elemental Solids and Ionic Compounds, Defect Classes, Point Defects, KrogerVink Notation, Point Defect Formation & Equilibrium, Law of MassAction and electrical neutrality, Thermodynamics of Intrinsic Defects and Defect Reactions. Complexes Containing an Impurity Center and an Ionic. Defect, Intrinsic Ionic Defect Associates and Effect of Impurities on the Concentration of Defect Complexes and Associate.Defect Equilibria in Pure and Stoichiometric Compounds with Schottky Defects, Frenkel Defect Pairs and Intrinsic Ionization of Electrons, **Course Reference**: 1 L.L. Hench and West, Electroceramics, Wiley; 2. D. M. Smyth;The Defect Chemistry of Metal Oxides; Publisher: Oxford University Press, ISBN10:01951101453; 3. Wei Gao and Nigel M. Sammes;An Introduction to Electronic and Ionic Materials; Publisher: WorldScientific; 4. A.J. Moulson & J. M. Herbert;Eiectroceramics: Materials, Properties, Applications;, Publisher: Wiley; 5. M. W. Barsoum;Fundamentals of Ceramics; Publisher: Institute of Physics; 6. Impedance Spectroscopy: Theory, Experiment and Applications; Edited by J. Ross Macdonald & EvgenijBarsoukov, Publisher: John Wiley and Sons; 7. Robert Huggins;Use of defect equilibrium diagrams to understand minority species transport in solid electrolytes; Solid State Ionics, 143 (2001) 316.
MSE631A	ELECTROCERAMIC MATERIALS AND APPLICATIONS	3-0-0-0-9	Introduction, FCC packed structures (MgO, Ce02 etc), HCP packed structures (LiNb03 etc), Other structures such as Perovskite (BaTi03 etc) and Rutile structures, Defects in Elemental Solids and Ionic Compounds, Defect Classes, Point Defects, KrogerVink Notation, Point Defect Formation & Equilibrium, Law of Mass Action and electrical neutrality, Thermodynamics of Intrinsic Defects and Defect Reactions. Complexes Containing an Impurity Center and an Ionic. Defect, Intrinsic Ionic Defect Associates and Effect of Impurities on the Concentration of Defect Complexes and Associate.Defect Equilibria in Pure and Stoichiometric Compounds with Schottky Defects, Frenkel Defect Pairs and Intrinsic Ionization of Electrons,

			Course Reference: 1. L.L. Hench and West, Electroceramics, Wiley; 2. D. M. Smyth;The Defect Chemistry of Metal Oxides; Publisher: Oxford University Press, ISBN10:01951101453; 3. Wei Gao and Nigel M. Sammes;An Introduction to Electronic and Ionic Materials; Publisher: World Scientific; 4. A.J. Moulson & J. M. Herbert; Eiectro ceramics: Materials, Properties, Applications; Publisher: Wiley; 5. M. W. Barsoum; Fundamentals of Ceramics; Publisher: Institute of Physics; 6. Impedance Spectroscopy: Theory, Experiment and Applications; Edited by J. Ross Macdonald & Evgenij Barsoukov, Publisher: John Wiley and Sons; 7. Robert Huggins;Use of defect equilibrium diagrams to understand minority species transport in solid electrolytes;, Solid State Ionics, 143 (2001) 316.
MSE634	FUNDAMENTALS OF SPRAY TECHNIQUES	3-0-0-0-4	Introduction Different Spray Techniques and their need Combustion Spraying: Flame Spraying DGunThermal Spraying Techniques: High Velocity oxyfuelPrinciple and Working Arc and Plasma Spraying: Wire/Powder Arc Spraying Plasma Spraying (Air/ Vacuum) Cold Spraying Spraying Parameters Inflight conditions Plasmal Primary/ Secondary/ Carrier gases Power rating Feed rate Standoff distance Substrate preparation Powde,r Powder size and distribution Powder Injection Reaction of particles Coating Formation Evaporation/Condensation Comparison of deposition techniques Single Splat Formation Heat transfer and spreading of splat Splay layering and deposition Microstructure and densification of deposited coatings Diagnostics and Coating Reliability Thermal and Kinetic Profiles Inflight particle sensor Control of Deposition parameters Bulk Nanostructure and Near Net Shape Microstructural distribution Design and control of bulk nanostructure Mandrel choice Mandrel removal Lectures Case Studies: Thermal Barrier/ Ultra high temperature ceramics **Course Reference**: 1. Handbook of thermal spray technology, Joseph R. Davis, ASM International. Thermal Spray SocietyTraining Committee (2004); 2. Advanced Structural Ceramics, Bikramjit Basu and Kantesh Balani, Wiley (2011). Will be supplemented with handout, and joumal publication.
MSE634A	FUNDAMENTALS OF SPRAY TECHNIQUES	3-0-0-0-9	Introduction Different Spray Techniques and their need Combustion Spraying: Flame Spraying DGunThermal Spraying Techniques: High Velocity oxyfuel Principle and Working Arc and Plasma Spraying: Wire/Powder Arc Spraying Plasma Spraying (Air/ Vacuum) Cold Spraying Parameters Inflight conditions Plasmal Primary/ Secondary/

			Carrier gases Power rating Feed rate Standoff distance Substrate preparation Powder Powder size and distribution Powder Injection Reaction of particles Coating Formation Evaporation/Condensation Comparison of deposition techniques Single Splat Formation Heat transfer and spreading of splat Splay layering and deposition Microstructure and densification of deposited coatings Diagnostics and Coating Reliability Thermal and Kinetic Profiles Inflight particle sensor Control of Deposition parameters Bulk Nanostructure and Near Net Shape Microstructural distribution Design and control of bulk nanostructure Mandrel choice Mandrel removal Lectures Case Studies: Thermal Barrier/ Ultra high temperature ceramics **Course Reference**: 1. Handbook of thermal spray technology, Joseph R. Davis, ASM International. Thermal Spray SocietyTraining Committee (2004); 2. Advanced Structural Ceramics, Bikramjit Basu and Kantesh Balani, Wiley (2011). will be supplemented with handout, and joumal publication.
MSE637	Nanotribology and Nanomechanics	3-0-0-0-4	Definition of micro/nano tribology Origin of tribology Measurement techniques Role of tribology in MEMS/NEMSN anotribology: Measurement techniques and Concepts AFM/FFM Role of Surface roughness Friction, scratching/wear and lubrication Local deformation Nanoindentation Surface elasticity/viscoelasticity. Surface maging, Friction and Adhesion Atomic scale imaging Friction: macro and microscale (Tomlinsonthermal/geometric effects) Surface roughness Nanoscale friction Wear mapping Lubricated adhesion and friction Multi length scale Wear, Scratching Nano and microscale wear Microscale scratching Insitu local deformation characterization Nanomachining Indentation Pico/Nano indentation Localised surface elasticity/viscoelasticity Load displacement curve, indenter geometry,stiffuess Boundary Lubrication Lubricants, monolayers Liquid thin films Nanomechanics and Testing Instrumentation: AFM, SPM Bulge tests, acoustic/imaging methods Defect Nucleation Scaling Effects Length scale effect on hardness, yield strength Roughness and contact parameters Model, Adhesion friction, 2 body and 3 body deformation, ratchet mechanism Scale effect on wear Case Studies Ultrathin amorphous carbon films Self assembled mono layers (for controlling adhesion,friction and wear) Nanotribology and nanomechanics of magnetic storage devices/ NEMS/MEMS Biomaterial/ Biological samples.

			Course Reference: 1. Introduction to Micromechanics and Nanomechanics, Shaofan Li and Gang Wang World Scientific Publishing Company (2008); 2. Fundamentals oftribology, Ramsey Gohar, Homer Rahnejat Imperial College Press (2008); 3. Advanced Structural Ceramics, Bikramjit Basu and Kantesh Balani, Wiley (2011); 4. course materials will be supplemented with handouts, and journal publications.
MSE638	SYMMETRY AND PROPERTIES OF CRYSTALS	3-0-0-0-4	Introduction 1 Symmetries in 1D, 2D and 3D, Examples of patterns showing various, symmetries, Symmetries and Lattices in 2D space : Operations of Translation, Rotation and Reflection, standard symbols, Lattices and Unit Cells, Permissible rotational symmetries, Derivation of lattices: oblique, rectangular, centred rectangular, square, hexagonal Point Groups in 2D; 4 : Set of symmetry operations, Group Theory Essentials, Evolution of 2D crystallographic point groups, 2D Space Groups (Plane Groups) Glide Planes: combination of lattice translation and reflection, Derivation of all the 17 plane groups, Understanding the Plane Group entries in the International Tables, of Crystallography3D Point Groups 4 : Combination of rotation axes in 3D, Development of the 32 point groups, Laue Groups3D Bravais Lattices Addition of a third translation to the plane groups, Derivation of Bravais Lattices3D Space Groups Screw Axes: combination of lattice translation and rotation, Development of the 230 space groups, Understanding the Space Groups entries in the International Tables of Crystallography **Course Reference**: 1. M.J. Buerger, Elementary Crystallography; 2. International Tables of Crystallography A, International Union of Crystallography; 3. J. F. Nye, Physical Properties of Crystals (1995), Oxford Science Publications; 4. D.R. Lovett, Tensor Properties of Crystals (1999), Institute of Physics Pub I ishing; 5. Robert E. Newnham; Properties of Materials: Anisotropy, Symmetry, Structure; Oxford Pr.
MSE638A	SYMMETRY AND PROPERTIES OF CRYSTALS	3-0-0-0-9	Introduction 1. Symmetries in 1 D, 2D and 3D, Examples of patterns showing various, symmetries, Symmetries and Lattices in 2D space : Operations of Translation, Rotation and Reflection, standard symbols, Lattices and Unit Cells, Permissible rotational symmetries, Derivation of lattices: oblique, rectangular, centred rectangular, square, hexagonal Point Groups in 2D : Set of symmetry operations, Group Theory Essentials, Evolution of 2D crystallographic point groups, 2D Space Groups (Plane Groups) Glide Planes: combination of lattice translation and reflection,

			Derivation of all the 17 plane groups, Understanding the Plane Group entries in the International Tables, of Crystallography 3D Point Groups 4 : Combination of rotation axes in 3D, Development of the 32 point groups, Laue Groups3D Bravais Lattices Addition of a third translation to the plane groups, Derivation of Bravais Lattices 3D Space Groups Screw Axes: combination of lattice translation and rotation, Development of the 230 space groups, Understanding the Space Groups entries in the International Tables of Crystallography **Course Reference**: 1. M.J. Buerger, Elementary Crystallography; 2. International Tables of Crystallography A, International Union of Crystallography; 3. J. F. Nye, Physical Properties of Crystals (1995), Oxford Science Publications; 4. D.R. Lovett, Tensor Properties of Crystals (1999), Institute of Physics Pub I ishing; 5. Robert E. Newnham; Properties of Materials: Anisotropy, Symmetry, Structure, Oxford Pr.
MSE639A	INTERFACES AND MATERIALS PROPERTIES		Course Outline: Surfaces and interfaces play extremely important role in determining the physical properties of materials. These become of critical important especially when materials approach nanoscale dimensions such as in the form of thin films and nanostructures. The objective of this course is to provide the UG/PG students of MSE department a background on the nature of various interfaces (Solid-Vapour, Solid- Liquid and Solid-Solid), their thermodynamics, their interactions, nature of defect surfaces and domains. Special emphasis will be paid towards understanding of the homophase (e.g. grain boundaries) and heterophase systems (e.g. epitaxial films). As part of case studies, the contents will elucidate a few metal and ceramic interface systems vis-a-vis their impact on the functional properties. Finally, the students will be exposed to the surface modification techniques that affect these interfaces and their functionality. 1) Introduction to the interfaces: basic classification and definitions 2) Basics of Energetics Definitions and relations to physical properties; Broken bond model; Gamma plotWulff plot and construction Solid-Vapour interfaces Surface structure (Terraces, ledges and kinks) and defects;Surface relaxation and reconstruction Phase transformations; Crystal growth from vapour (Nucleation and Growth, Vicinal surfaces; Surface films 4) Solid-Liquid Interfaces; Structure and properties of liquids; Interfacial structure and energy Crystal growth; Solute partitioning and morphological stability; Electrical aspects of

			surfaces and surface chemistry such as electrical double layer, zeta potential 5) Solid-Solid Interfaces a) Tyesflsldiercesdbscs b) phase Interfaces; Grain boundary structure and energy; Types of grain boundaries and dislocation models; Stacking Fault and Twin Boundaries; Grain Boundary; Grain boundary and twin boundary equilibria; Domains in ferroelectric and ferromagnetic systems: energetic; c) Hetero-phase Interfaces; Interphase boundaries; Coherent and semcoherent interphase boundaries and their energetic; Roughening and Phase transformations on interphase boundaries; Antiphase Boundaries; Interfaces between differences materials and structures; Terrace-ledge and kink models; Growth, morphology and segregation at the heterophase interfaces 6) Interfaces and Functional Behaviour: Case Studies; Effect of interfaces in mechanical properties; Effect on the strength of materials; High temperature behaviour: Creep; Grain boundary engineering, sliding and migration; Fracture;metals and alloys: surface ;embrittlement, grain boundary; embrittlement, failure of ceramics and interface strengthening; Friction and adhesion; Electrical Properties; Role of interfaces in conduction in metals and ceramics; Interfaces effects in dielectrics, ferroelectrics and piezo electrics and their; thin films and hetero structures, domains and grain boundaries; Hetero structures; strain ;and epitaxy and their effects on;functional behavior; Interface effects on the magnetic properties of bulk magnetic materials and thin film devices; Interfaces in optical devices with emphasis on the solar cells and displays 7) Surface modification and impact on properties; Interfaces in Materials: Atomic Structure, Thermodynamics and Kinetics of Solid-Vapor, Solid-Liquid and Solid-Solid Interfaces, James M. Howe, Wiley-Interscience; Physics and chemistry of interfaces By Hans-gen Butt, Karlheinz Graf, Michael Kappl, Wiley-VCH; Physics of surfaces and interfaces, H. Ibach, Springer; Solid surfaces, interfaces and thin films, Hans Lüth, Springer; Physical Chemistry of Surfaces, Arthur W. Adamson, Wiley-Interscience
MSE642	MICROSCOPY AND MICROANALYSIS OF MATERIALS	3-0-0-0-4	Advanced Optical microscopy: Special microscopy techniques and applications: Bright field and dark field imaging; confocal microscopy; interference microscopy; polarized light microscopy; phase contrast microscopy. Scanning near field laser microscopy Image processing and quantification Scanning electron microscope: Basis of image contrast and various operating modes in SEM SE and BSE, Xray, EBIC, cathodoluminescence, voltage contrast mode, Magnetic contrast mode.

			(2) Environmental SEM, Low voltage SEM, and applications (I) Electron back scattered diffraction /OM: Basic principles, the microtextural data acquisition and analysis, applications (3) Fractography and failure analysis (2) Transmission electron microscope: Wave properties of electrons, lens defects, aberration corrected TEM and sub Angstrom resolution (2L) Origin of contrast: mass thickness contrast, diffraction contrast and crystal defect analysis. Dynamic diffraction and anomalous absorption effects, image artifacts (3L) BF, OF, Weak beam OF images and applications (I L) Electron Diffraction: SADP, Micro diffraction, CBED. Diffuse scattering and finestructure in Diffraction pattern. (2L) Phase contrast and HRTEM: Contrast transfer function and lattice imaging, Computer simulation of lattice and structural images, Interpretation of images and illustrative examples (2L) STEMHAADF imaging, information limit (lL) Lorentz microscopy and holography (1) Specimen preparation: Mechanical thinning, electrochemical thinning, ion milling, sputter coating and carbon coating, replica methods (2L) **Course Reference**: 1. Fundamental of light microscopy and electronic imaging, 0.8. Murphy, WileyLiss, 2001; 2. Microstructural Characterization of Materials D. Brandon and W.D. Kaplan, John Wiley and Sons,2008; 3. Scanning Electron Microscopy & XRay Microanalysis, J. Goldstein et.al, Springer, 2003; 4. Transmission Electron Microscopy B.D. Will iams & C. B. Carter, Springer, 2009; 5. Science of Microscopy, P.W. Hawkes and J.C.H. Spen(:e, Springer, 2007; 6. Surface Analysis methods in materials science, Editors: D.J.O; Connor, B.A. Sextton, R.St. C. Smart, Springer, 2003; 7. Materials Characterisation Techniques, S. Zhang, Lin Li and Ashok Kumar, CRC Press, 2009; 8. Fundamentals of Materials Sciencethe microstructure property relationship using metals as model systems, E.J. Mittemeijer, Springer, 2010
MSE642A	MICROSCOPY AND MICROANALYSIS OF MATERIALS	3-0-0-0-9	Advanced Optical microscopy: Special microscopy techniques and applications: Bright field and dark field imaging; confocal microscopy; interference microscopy; polarized light microscopy; phase contrast microscopy. Scanning near field laser microscopy Image processing and quantification Scanning electron microscope: Basis of image contrast and various operating modes in SEM SE and BSE, Xray, EBIC, cathodoluminescence, voltage contrast mode, Magnetic contrast mode. (2) Environmental SEM, Low voltage SEM, and applications (I) Electron back scattered diffraction

			/OM: Basic principles, the micro textural data acquisition and analysis, applications (3) Fracto graphy and failure analysis (2) Transmission electron microscope: Wave properties of electrons, lens defects, aberration corrected TEM and subAngstrom resolution (2L) Origin of contrast: mass thickness contrast, diffraction contrast and crystal defect analysis. Dynamic diffraction and anomalous absorption effects, image artifacts (3L) BF, OF, Weak beam OF images and applications (IL) Electron Diffraction: SADP, Micro diffraction, CBED. Diffuse scattering and fine structure in Diffraction pattern. (2L) Phase contrast and HRTEM: Contrast transfer function and lattice imaging, Computer simulation of lattice and structural images, Interpretation of images and illustrative examples (2L) STEMHAADF imaging, information limit (lL) Lorentz microscopy and holography (1) Specimen preparation: Mechanical thinning, electrochemical thinning, ion milling, sputter coating and carbon coating, replica methods (2L). **Course Reference:** 1. Fundamental of light microscopy and electronic imaging, 0.8. Murphy, WileyLiss, 2001; 2. Microstructural Characterization of Materials D. Brandon and W.D. Kaplan, John Wiley and Sons,2008; 3. Scanning Electron Microscopy & XRay Microanalysis, J. Goldstein et.al, Springer, 2003; 4. Transmission Electron Microscopy B.D. Will iams & C. B. Carter, Springer, 2009; 5. Science of Microscopy, P.W. Hawkes and J.C.H. Spen(:e, Springer, 2007; 6. Surface Analysis methods in materials science, Editors: D.J.O; Connor, B.A. Sextton, R.St. C. Smart, Springer, 2003; 7. Materials Characterisation Techniques, S. Zhang, Lin Li and Ashok Kumar, CRC Press, 2009; 8. Fundamentals of Materials Sciencethe microstructure property relationship using metals as model systems, E.J. Mittemeijer, Springer, 2010
MSE646	X-RAY CRYSTALLOGRAPHY - I	3-0-0--4	Elemental compound and alloy crystals, modes of bonding, crystal types, densityof packing, atomic stacking, inter atomic voids, coordination polyhedra, Paulings rules, symmetry elements, space and point groups, group theoretical formulation, diffraction or radiation.
MSE648	DIFFUSION IN SOLIDS	3-0-0--4	Diffusion equations and mathematical solutions: Phenomenological diffusion theories: Atomic theory of diffusion, theoretical and experimental investigation of diffusion phenomena: Diffusion in ionic solids and semiconductors: Grain boundary and surface diffusion, thermal and electro diffusion.
MSE648A	DIFFUSION IN SOLIDS	3-0-0-0-9	Diffusion equations and mathematical solutions: Phenomenological diffusion theories: Atomic theory

			of diffusion, theoretical and experimental investigation of diffusion phenomena: Diffusion in ionic solids and semiconductors: Grain boundary and surface diffusion, thermal and electrodiffusion.
MSE650	FUNDAMENTALS OF STEREOLOGY & APPLICATIONS TO MICROSTRUTURAL ANALYSIS	3-0-0--4	Concepts and language of stereology; geometrical probability; fundamental operations in stereology; averaging with respect to orientation; basic stereological parameters on true 2D sections and thick sections; topological parameters of microstructure; error analysis; applications of analysis of optical, scanning and transmission electron micrographs; numerical density and size distribution of particles and grains of various shapes and sizes; stereological analysis of anisotropic microstructures; fractal description of various microstructures; fractal dimensions and its significance; applications to characterization of martensitic, polycrystalline and other structures and fracture surfaces.
MSE650A	FUNDAMENTALS OF STEREOLOGY & APPLICATIONS TO MICROSTRUTURAL ANALYSIS	3-0-0-0-9	Concepts and language of stereology; geometrical probability; fundamental operations in stereology; averaging with respect to orientation; basic stereological parameters on true 2D sections and thick sections; topological parameters of microstructure; error analysis; applications of analysis of optical, scanning and transmission electron micrographs; numerical density and size distribution of particles and grains of various shapes and sizes; stereological analysis ofanisotropic microstructures; fractal description of various microstructures;fractal dimensions and its significance; applications to characterization of martensitic, polycrystalline and other structures and fracture surfaces.
MSE653	TRANSMISSION ELECTRON MICROSCOPY & NANO-ANALYSIS OF MATERIALS	3-0-0-0-4	1. Introduction: History, Interaction of electrons with matter, Different kinds of TEMs; 2. Electron scattering and diffraction: Terminology of scattering Interaction cross section; concept of mean free path; Scattering in the TEM; Fraunhofer and Fresnel diffraction; electron diffraction patterns; 3. Elastic and inelastic scattering in TEM: Elastic scattering mechanisms; scattering at isolated atoms, atomic scattering factor, the structure factor, simple diffraction concepts. Inelastic processes occur in the tern; 4. Diffraction in TEM and diffraction techniques: diffraction in the tern and dynamical effects; practical aspects of diffraction pattern formation; reciprocal lattice, vector g, Ewald sphere of reflection; excitation error; diffraction from long period super lattices, sniall volumes, wedge shaped specimens, planar defects, particles, dislocations, etc. CBED patterns, comparing sad and CBED. **Course Reference** : 1. Transmission Electron

			Microscopy B.D. Williams & C.B.Carter, Springer, 2009; 2. Aberration corrected analytical transmission electron microscopy, Ric Brydson, Wiley, 2011; 3. Analytical electron microscopy for materials science, D. Shindo and T. Oikawa, Springer, 2002; 4. Introduction to conventional electron microscopy, Marc De Graef, Cambridge University Press, 2005; 5. Science of Microscopy, P.W. Hawkes and J.C.H. Spence, Springer, 2007; 6. Insitu electron microscopy at high resolution, Editor: Flrian Banhart, World Scientific, 2008; 7. Materials Characterisation Techniques, S. Zhang, Lin Li and Ashok Kumar, CRC Press, 2009; 8. Handbook of Microscopy: Applications in materials science, solidstate phsysics and chemistry. EditedBy: S. Amelinckx, D. van Dyck, J. van Landuyt, ad G. van Tendeloo, VCH, Weinheim, 1997; 9. Microstructural Characterization of Materials D. Brandon and W.D. Kaplan, John Wiley and Sons,2008
MSE653A	TRANSMISSION ELECTRON MICROSCOPY & NANO-ANALYSIS OF MATERIALS	3-0-0-0-9	1. Introduction: History, Interaction of electrons with matter, Different kinds of TEMs; 2. Electron scattering and diffraction: Terminology of scattering Interaction cross section; concept of mean free path; Scattering in the TEM; Fraunhofer and Fresnel diffraction; electron diffraction patterns; 3. Elastic and inelastic scattering in TEM: Elastic scattering mechanisms; scattering at isolated atoms, atomic scattering factor, the structure factor, simple diffraction concepts. Inelastic processes occur in the tern; 4. Diffraction in TEM and diffraction techniques: diffraction in the tern and dynamical effects; practical aspects of diffraction pattern formation; reciprocal lattice, vector g, Ewald sphere of reflection; excitation error; diffraction from longperiod superlattices, sniall volumes, wedge shaped specimens, planar defects, particles, dislocations, etc. CBED patterns, comparing sad and CBED.
MSE655	MODERN TRENDS IN METAL FORMING PROCESESS	3-0-0--4	Limitation of conventional metal forming methods: Powder rolling and its various variants, spray rolling, direct strip process: Powder, spray, rotary and isothermal forging: Hydrostatic and powder extrusion: Conform process: Applications ofthese processes for making conventional and speciality products.
MSE657	Deformation Processing	3-0-0-4-4	Slip planes and systems in various crystal systems; Elasticity and Plasticity; Deformation processes including Rolling; Forging, Extrusion; Drawing and deep drawing etc.; Deformation of plastics and polymers; superplastieity; Formability; Failures; Friction wear and lubrication **Course Reference**: 1. Hosford, W. F., and Cadell, R. M., 2007, Metal Forming: Mechanics and

			Metallurgy, Cambridge University Press, Cambridge; 2. George Dieter, 1986, Mechanical Metallurgy, McGraw Hill.
MSE658	DISLOCATIONS AND PLASTICITY	3-0-0-0-4	Overview of defects in Materials: (point, line, planar and volume defects) and their classification. Overview of plastic deformation mechanisms. Point defects: interaction and distributions, statistical thermodynamics, role in diffusion and deformation. Basic understanding of dislocations using physical and computer models: the Volterra cut, Burgers vector and the Burgers circuit, the line vector, edge, screw and mixed locations, Role of dislocations in weakening the crystal and in plasticity. Elasticity theory of dislocations: Stress, strain and displacement fields and energy of a dislocation, Forces on dislocations (including image force) Interaction between dislocations, Core of a dislocation. Motion of dislocations: The Peierls stress, role of the core structure, interaction of dislocations with other defects (including yield point phenomenon); kinks; jogs; crossslip; climb, Temperature and strainrate dependence of flow stress, Dislocation dynamics and the tensile stressstrain curve. Dislocations in FCC Metals: Partial dislocations (Shockley and Frank partials) stacking faults, Thompson’s tetrahedron, Lomer Cotrell sessile dislocation. Overview of dislocations in other crystal structures: HCP metals, BCC metals, ionic crystals, super lattices, covalent crystals. Origin and multiplication of dislocations: dislocations in freshly grown crystals, nucleation of dislocations, multiplication of dislocations (by FrankRead sources, cross slip and climb), Grain boundary sources, Recovery and recrystallization. Geometrically/structurally necessary dislocations: lowangle & general grain boundaries, indentation, interfacial dislocations, Twinning including incoherent twins. Specific examples of role of dislocations and case studies: Dislocations in nanocrystals, The HallPetch relation and the Inverse HallPetch Effect (IHPE), Dislocations in epitaxial systems, Severe Plastic deformation, Role of dislocations in Creep, Fatigue and Fracture. **Course Reference**: 1. Introduction to Dislocations, D. Hull and D.J. Bacon, Pergamon Press, Oxford, 1984; 2. Theory of Dislocations, J. P. Hirth and J. Lothe, McGrawHill, New York, 1968; 3. Crystal Defects and Crystalline Interfaces, W. Bollmann, SpringerVerlag, Berlin, 1970; 4. Elementary Dislocation Theory, J. Weertman and J. Weertman, The MacMillian Company, New York, 1964; 5. http://www.tf.unikiel.de/matwis/amat/def_en/
MSE658A	DISLOCATIONS AND PLASTICITY	3-0-0-0-9	Overview of defects in Materials: (point, line, planar and volume defects) and their classification.

			Overview of plastic deformation mechanisms. Point defects: interaction and distributions, statistical thermodynamics, role in diffusion and deformation. Basic understanding of dislocations using physical and computer models: the Volterra cut, Burgers vector and the Burgers circuit, the line vector, edge, screw and mixed locations, Role of dislocations in weakening the crystal and in plasticity. Elasticity theory of dislocations: Stress, strain and displacement fields and energy of a dislocation, Forces on dislocations (including image force) Interaction between dislocations, Core of a dislocation. Motion of dislocations: The Peierls stress, role of the core structure, interaction of dislocations with other defects (including yield point phenomenon); kinks; jogs; crossslip; climb, Temperature and strainrate dependence of flow stress, Dislocation dynamics and the tensile stressstrain curve. Dislocations in FCC Metals: Partial dislocations (Shockley and Frank partials) stacking faults, Thompson's tetrahedron, LomerCotrell sessile dislocation. Overview of dislocations in other crystal structures: HCP metals, BCC metals, ionic crystals, superlattices, covalent crystals. Origin and multiplication of dislocations: dislocations in freshly grown crystals, nucleation of dislocations, multiplication of dislocations (by Frank Read sources, cross slip and climb), Grain boundary sources, Recovery and recrystallization. Geometrically/structurally necessary dislocations: lowangle & general grain boundaries, indentation, interfacial dislocations, Twinning including incoherent twins. Specific examples of role of dislocations and case studies: Dislocations in nanocrystals, The HallPetch relation and the Inverse HallPetch Effect (IHPE), Dislocations in epitaxial systems, Severe Plastic deformation, Role of dislocations in Creep, Fatigue and Fracture. **Course Reference**: 1. Introduction to Dislocations, D. Hull and D.J. Bacon, Pergamon Press, Oxford, 1984; 2. Theory of Dislocations, J. P. Hirth and J. Lothe, McGrawHill, New York, 1968; 3. Crystal Defects and Crystalline Interfaces, W. Bollmann, SpringerVerlag, Berlin, 1970; 4. Elementary Dislocation Theory, J. Weertman and J. Weertman, The MacMillian Company, New York, 1964; 5. http://www.tf.unikiel.de/matwis/amat/def_en/
MSE659	POWDER METALLURGY	3-0-0-0-4	Powder Production (Chemical Methods, Electrolytic Methods, Atomization, Mechanical Methods),Powder Characterization (Chemical Composition and Structure, Particle Size and Surface Topography,Pyrophorocity and Toxic/ty), Powder Compaction, Phenomenological Aspects of

			Sintering, Solid State Sintering, Analytical Approach to Sintering, NonIsothermal Sintering, Microstructural Evolution, Liquid Phase Sintering, Stages of Liquid Phase Sintering, Super solidus Sintering, Activated Sintering, Pressure Assisted Sintering, Microwave Sintering, Select Case Studies. **Course Reference**: 1. R.M. German, Powder Metallugy Science, ed. John Wiley, 1999; 2. A. Upadhyaya, G.S. Upadhyaya, Powder Metallurgy: Science, Technology and Materials, 2011; 3. ASM Handbook, Volume 7: Powder Metal Technologies & Applications (1998)
MSE659A	POWDER METALLURGY	3-0-0-0-9	Powder Production (Chemical Methods, Electrolytic Methods, Atomization, Mechanical Methods), Powder Characterization (Chemical Composition and Structure, Particle Size and Surface Topography, Pyrophorocity and Toxic/ty), Powder Compaction, Phenomeno logical Aspects of Sintering, SolidState Sintering, Analytical Approach to Sintering, Non Isothermal Sintering, Microstructural Evolution, Liquid Phase Sintering, Stages of Liquid Phase Sintering, Supersolidus Sintering, Activated Sintering, Pressure Assisted Sintering, Microwave Sintering, Select Case Studies. **Course Reference**: 1. R.M. German, Powder Metallugy Science, d ed. John Wiley, 1999; 2. A. Upadhyaya, G.S. Upadhyaya, Powder Metallurgy: Science, Technology and Materials, 20 II; 3. ASM Handbook, Volume 7: Powder Metal Technologies & Applications (1998)
MSE663	ELECTRICAL AND MAGNETIC PROPERTIES OF CERAMIC MATERIALS	3-0-0--4	Structure of oxides: Ionic diffusion in oxides: Defect structure of nonstoichiometric compounds: Conductivity dependence on partial pressure of oxygen: Macroscopic characterization of dielectric materials: Electronic, atomic dipole, space charge polarization: Relaxation phenomeno adebyetic equations: Ferroelectrics: Diamagnetism, paramagnetism and ferromagnetism, exchange ferromagnetic domain: Structure and properties of ferrites.
MSE664	SOLID STATE IONICS	3-0-0-0-4	Perfect Structure, Defects in Elemental Solid and Ionic Compound, Defect Classes, Point Defects, KrogerVink Notation for Point Defects, Point Defect Formation & Equilibrium, Law of Massaction, Thermodynamic Related to Intrinsic Defects and Defect Reactions. Complexes Containing an Impurity Center and an Ionic Defect, Intrinsic Ionic Defect Associates and Effect of Impurities on the Concentration of Defect Complexes and Associate. Basic Concepts of Diffusion, Tracer Diffusion, Self Diffusion, Chemical Diffusion, Ambipolar Diffusion, Ionic Conduction in Crystalline Solid, Intrinsic

			andExtrinsic Ionic Conduction, Transference Number, Nernst Einstein Relationship, and Conductivity Diffusion Relationship. Defect Equilibria in Pure and Stoichiometric Compounds with Schottky Defects, Frenkel Defect Pairs and Intrinsic Ionization of Electrons, Defect Equilibria in Nonstoichiometric Oxides such as Oxygen Deficient Oxide, Oxide with excess Metal, Metal Deficient Oxide, Metal Oxide with Excess Oxygen. Brouwer Diagrams for YSZ, Undoped and Doped Ce02, Ti02 and BaTi03 Electrical Characterization Techniques such as AC Electrochemical Impedance Spectroscopy, Four Point Probe D.C. Method, Van Der Pauw Method, IV Curves, Blocking Electrodes, and HebbWagner Method. OpenCircuit Potential, Efficiency, Nernst Equation Analysis, Activation Losses (Tafel Equation), Ohmic Losses, Concentration Losses. Description of Operation, Configurations, Cell Components, Materials Requirements, Manufacturing Techniques, and Performance of the following electrochemical devices such Solid Oxide Fuel Cells, Gas Sensors and Batteries. **Course Reference**: 1. 1.D. M. Smyth;The Defect Chemistry of Metal Oxides, Publisher: Oxford University Press,ISBNIO: 0195110145; 2. A.J. Moulson & J. M. Herbert; Electroceramics: Materials, Properties, Applications, Publisher: Springer; 3. M. W. Barsoum, Fundamentals of Ceramics, Publisher: Institute of Physics; Impedance Spectroscopy: Theory, Experiment and Applications, Edited by J. Ross Macdonald & Evgenij Barsoukov, Publisher: John Wiley and Sons; 5. Robert Huggins;Use of defect equilibrium diagrams to understand minority species transport in solid electrolytes, Solid State Ionics, 143 (200 I) 316; 6. CRC Handbook of Solid State Electrochemistry; Edited by P. J. Gellings & H. J. M.Bouwmeester, Publisher: CRC Press; 7. High Temperature Solid Oxide Fuel Cells, Fundamental, Design and Applications , Edited by Subhash C. Singhal & Kevin Kendall, Publisher: Elsevier
MSE664A	SOLID STATE IONICS	3-0-0-0-9	Perfect Structure, Defects in Elemental Solid and Ionic Compound, Defect Classes, Point Defects, KrogerVink Notation for Point Defects, Point Defect Formation & Equilibrium, Law of Massaction, Thermodynamic Related to Intrinsic Defects and Defect Reactions. Complexes Containing an Impurity Center and an Ionic Defect, Intrinsic Ionic Defect Associates and Effect of Impurities on the Concentration of Defect Complexes and Associate. Basic Concepts of Diffusion, Tracer Diffusion, Self Diffusion, Chemical Diffusion, Ambipolar Diffusion, Ionic Conduction in Crystalline Solid, Intrinsic and

			Extrinsic Ionic Conduction, Transference Number, Nernst Einstein Relationship, and Conductivity Diffusion Relationship. Defect Equilibria in Pure and Stoichiometric Compounds with Schottky Defects, Frenkel Defect Pairs and Intrinsic Ionization of Electrons, Defect Equilibria in Nonstoichiometric Oxides such as Oxygen Deficient Oxide, Oxide with excess Metal, Metal Deficient Oxide, Metal Oxide with Excess Oxygen. Brouwer Diagrams for YSZ, Undoped and Doped Ce02, Ti02 and BaTi03 Electrical Characterization Techniques such as AC Electrochemical Impedance Spectroscopy, Four Point Probe D.C. Method, Van Der Pauw Method, IV Curves, Blocking Electrodes, and Hebb Wagner Method. Open Circuit Potential, Efficiency, Nernst Equation Analysis, Activation Losses (Tafel Equation), Ohmic Losses, Concentration Losses. Description of Operation, Configurations, Cell Components, Materials Requirements, Manufacturing Techniques, and Performance of the following electrochemical devices such Solid Oxide Fuel Cells, Gas Sensors and Batteries. **Course Reference**: 1. D. M. Smyth, ;The Defect Chemistry of Metal Oxides; Publisher: Oxford University Press,ISBNIO: 0195110145; 2. A.J. Moulson & J. M. Herbert, Electroceramics: Materials, Properties, Applications, Publisher: Springer; 3. M. W. Barsoum;Fundamentals of Ceramics;, Publisher: Institute of Physics; 4. Impedance Spectroscopy: Theory, Experiment and Applications, Edited by J. Ross Macdonald & Evgenij Barsoukov, Publisher: John Wiley and Sons; 5. Robert Huggins;Use of defect equilibrium diagrams to understand minority species transport in solid electrolytes;, Solid State Ionics, 143 (200I) 316; 6.CRC Handbook of Solid State Electrochemistry; Edited by P. J. Gellings & H. J. M.Bouwmeester, Publisher: CRC Press; 7. High Temperature Solid Oxide Fuel Cells, Fundamental, Design and Applications; Edited by Subhash C. Singhal & Kevin Kendall, Publisher: Elsevier
MSE665	PRACTICAL TRANSMISSION ELECTRON MICROSCOPY & NANOANALYSIS OF MATERIALS	3-0-0-0-4	Specimen preparation for TEM analysis : Metallic self supporting samples Electropolishing Ceramics and electronic devices: Cross sectional specimen preparation Ion Milling Soft materials, polymers, biological specimens: Ultramicrotomy Powders, Nanoparticles, fibres, fragments Focused Ion Beam techniques Importance and use of Plasma CleanersTEM: Instrumental details and requirements : Physics of Different Electron Sources:Lenses, Ape11ures, and Resolution: Electron Detection Display and Image Recording Pumps and Holders Operating modes, Illumination

			System, alignment and aberration correction caliberations : Forming DPs and Images; STEM Imaging System: Alignment and Stigmation Lens Rotation Centers, Correction of Astigmatism in the Imaging Lenses, Calibrating the Imaging System; Magnification Calibration, Camera Length Caltbration;Electron Diffraction and diffraction techniques: Practical aspects of diffraction and diffraction pattern analysis Mathematical Definition ofthe Reciprocal Lattice; Laue Equations and their Relation to Bragg's Law, Ewald Sphere of Reflection; The Excitation Error Experimental SAD Techniques, Indexing Single Crystal DPs, Ring Patterns from Polycrystalline Materials, HollowCone Diffraction, Amorphous Materials Precession Diffraction, Double Diffraction, Orientation ofthe Specimen, Orientation Relationships Amplitude contrast imaging and image interpretations : Image artifacts in TEM Systematic Crystal defect analysis: Dislocation analysis, stacking fault analysis, Grain boundaries and Interphase interface boundaries Volume Defects and Particles **Course Reference**: 1. Transmission Electron Microscopy B.D. Williams & C.B.Carter, Springer, 2009; 2. Sample preparation handbook for TEM: Methodology, J. Ayache et al., Springer, 2010; 3. Sample preparation handbook for TEM: Techniques, J. Ayache et al., Springer, 2010; 4. Aberration corrected analytical transmission electron microscopy, Ric Brydson, Wiley, 2011; 5. Analytical electron microscopy for materials science, D. Shindo and T. Oikawa, Springer, 2002; 6. Handbook of Microscopy: Applications in materials science, solidstate phsysics and chemistry. Edited By: S. Amelinckx, D. van Dyck, J. van Landuyt, ad G. van Tendeloo, VCH, Weinheim, 1997; 7. Microstructural Characterization of Materials D. Brandon and W.O. Kaplan, John Wiley and Sons,2008.
MSE665A	PRACTICAL TRANSMISSION ELECTRON MICROSCOPY & NANOANALYSIS OF MATERIALS	3-0-0-0-9	Specimen preparation for TEM analysis : Metallic self supporting samples Electropolishing Ceramics and electronic devices: Cross sectional specimen preparation Ion Milling Soft materials, polymers, biological specimens: Ultramicrotomy Powders, Nanoparticles, fibres, fragments Focused Ion Beam techniques Importance and use of Plasma CleanersTEM: Instrumental details and requirements : Physics of Different Electron Sources:Lenses, Ape11ures, and Resolution: Electron Detection Display and Image Recording Pumps and Holders Operating modes, Illumination System, alignment and aberration correction caliberations : Forming DPs and Images; STEM

			Imaging System: Alignment and Stigmation Lens Rotation Centers, Correction of Astigmatism in the Imaging Lenses, Calibrating the Imaging System; Magnification Calibration, Camera Length Caltbration;Electron Diffraction and diffraction techniques : Practical aspects of diffraction and diffraction pattern analysis Mathematical Definition ofthe Reciprocal Lattice; Laue Equations and their Relation to Bragg's Law, Ewald Sphere of Reflection; The Excitation Error Experimental SAD Techniques, Indexing SingleCrystal DPs, Ring Patterns from Polycrystalline Materials, HollowCone Diffraction, Amorphous Materials Precession Diffraction, Double Diffraction, Orientation ofthe Specimen, Orientation Relationships Amplitude contrast imaging and image interpretations : Image artifacts in TEM Systematic Crystal defect analysis: Dislocation analysis, stacking fault analysis, Grain boundaries and Interphase interface boundaries Volume Defects and Particles **Course Reference**: 1. Transmission Electron Microscopy B.D. Williams & C.B.Carter, Springer, 2009; 2. Sample preparation handbook for TEM: Methodology, J. Ayache et al., Springer, 2010; 3. Sample preparation handbook for TEM: Techniques, J. Ayache et al., Springer, 2010; 4. Aberration corrected analytical transmission electron microscopy, Ric Brydson, Wiley, 2011; 5. Analytical electron microscopy for materials science, D. Shindo and T. Oikawa, Springer, 2002; 6. Handbook of Microscopy: Applications in materials science, solidstate phsysics and chemistry. Edited By: S. Amelinckx, D. van Dyck, J. van Landuyt, ad G. van Tendeloo, VCH, Weinheim, 1997; 7. Microstructural Characterization of Materials D. Brandon and W.O. Kaplan, John Wiley and Sons,2008
MSE666	SCIENCE AND TECHNOLOGY OF MAGNETIC MATERIALS	3-0-0--4	Magnetic units: Magnetic moments: Dia, para and paulipara magnetism, Molecular field: Ferro, antiferro and ferrimagnetism: Alloying effect on transition metals and intermetallics: Stability of domain structure: Origin of magnetic anisotropy and its application: Effect of inclusions, internal stress, magnetostriction and preferred orientation on magnetization: Susceptibility and coercivity calculations: Magnetic thin filmsa morphous and crystalline, soft and permanent magnets: Technological aspects of magnetic materials.
MSE667	SELECTION AND DESIGNING WITH ENGINEERING MATERIALS	3-0-0--4	Overview of the design process: concepts and stages of engineering design anddesign alternatives to develop materials with tailored properties; Performance indices of materials; function, objective and constraints in design,

			specific stiffness limited and strength limited design for maximum performance,Performance indices for thermal, mechanical, thermo mechanical applications,damage tolerant designs for structural applications; Basic concepts of materials science: processing structure property performance correlation; overview of conventional and advanced materials; Brief overview of the elements of chemical bonding, crystal structure, defect structure of different material classes, Brief introduction to the manufacturing processes for metals, polymers, ceramics,glasses and composite materials; design for manufacturability, Ashbys material property charts; Decision matrices and decision matrix techniques in materials selection, relationship between materials selection and processing; Case studies:designing of Metals and alloys, ceramics and glasses, composite materials (MMC,CMC and PMC/ FRC) for specific applications.
MSE668	MATERIALS FOR BIOMEDICAL APPLICATIONS	3-0-0--4	Introduction to basic concepts of Materials Science; Salient properties of important material classes; Property requirement of biomaterials; Concept of biocompatibility; cellmaterial interactions and foreign body response; assessmentof biocompatibility of biomaterials, important biometallic alloys; Tibased,stainless steels, CoCrMo alloys; Bioinert, Bioactive and bioresorbable ceramics;Processing and properties of different bioceramic materials with emphasize on hydroxyapatite; synthesis of biocompatible coatings on structural impant materials; Microstructure and properties of glassceramics; biodegradable polymers; Design concept of developing new materials for bioimplant applications.
MSE670	SOLIDIFICATION PROCESSING	3-0-0-0-4	Thermodynamics of solidification, Nucleation and growth, Pure metal solidification, Gibbs Thomson effect, Alloy Solidification: Mathematical Analysis of redistribution of solute during solidification,Constitutional undercooling, Mullins Sekerka instability, Dendritic growth , Multi phase solidification: eutectic and peritectic, Structure of casting and ingots, Types of casting, Heat transfer, Design of riser andgating, Joining, different joining processes, Fusion welding, Solidification, heat transfer, fluid flow duringfusion welding, Modelling of solidification under different conditions **Course Reference** : 1. Solidification Processing; Fleming, M.C., McGrawHill, N.Y., 1974; 2. Solidification ofCasting; Ruddle, R.W., Institute ofMetals, 1957; 3. Solidification and Casting, Davies, G.J., John Wiley and Sons, 1973; 4. Science and Engineering of Casting Solidification;

			Stefanescu, D.M., Kluwar Publications, 2002; 5. Fundamentals of Solidification by Kurz, W. and Fisher, D.J.,TransTech Publications, Switzerland,1989; 6. Applied Welding Engineering: Process, Codes and Standard; R.Singh,. Elsevier Inc.,2012
MSE670A	SOLIDIFICATION PROCESSING	3-0-0-0-9	Thermodynamics of solidification, Nucleation and growth, Pure metal solidification, Gibbs Thomson effect, Alloy Solidification: Mathematical Analysis of redistribution of solute during solidification, Constitutional undercooling, MullinsSekerka instability, Dendritic growth , Multi phase solidification: eutectic and peritectic, Structure of casting and ingots, Types of casting, Heat transfer, Design of riser andgating, Joining, different joining processes, Fusion welding, Solidification, heat transfer, fluid flow duringfusion welding, Modelling of solidification under different conditions **Course Reference** : I. Solidification Processing; Fleming, M.C., McGrawHill, N.Y., 1974; 2. Solidification ofCasting; Ruddle, R.W., Institute ofMetals, 1957; 3. Solidification and Casting, Davies, G.J., John Wiley and Sons, 1973; 4. Science and Engineering of Casting Solidification; Stefanescu, D.M., Kluwar Publications, 2002; 5. Fundamentals of Solidification by Kurz, W. and Fisher, D.J, TransTech Publications, Switzerland,1989; 6. Applied Welding Engineering: Process, Codes and Standard; R.Singh,. Elsevier Inc.,2012
MSE671	HEAT TREATMENT AND SURFACE HARDENING	3-0-0-0-4	Introduction, Theory of Heat Treatment, Heat Treatment Environment, Different Heat Treatment Techniques, Fundamentals and Properties; Annealing, Tempering, Hardening, Thermo mechanical treatment, Fundamentals of Surface Hardening Treatment, Carburizing, Carbonitriding, Nitriding, Modern surface hardening techniques; Economy of Heat Treatment Processes **Course Reference**:1. Principles of Heat Treatment of Steels by R.C. Sharma; 2. The, Heat Treating Source Book, ASM, 1986; 3. Heat Treatment of Metals by W.S. Owen (1963) (Institute for Metallurgists); 4. Engineering Physical Metallurgy and Heat Treatment by Y. Lakhtein (Mir Publisher); 5. Phase Transformations in Metals and Alloys by D.A. Porter and K.E. Easterling (Taylor andFrancis)
MSE671A	HEAT TREATMENT AND SURFACE HARDENING	3-0-0-0-9	Introduction, Theory of Heat Treatment, Heat Treatment Environment, Different Heat Treatment Techniques, Fundamentals and Properties; Annealing, Tempering, Hardening, Thermomechanical treatment, Fundamentals of Surface Hardening Treatment, Carburizing, Carbonitriding, Nitriding, Modern surface hardening techniques; Economy of Heat Treatment

			Processes **Course Reference**:1. Principles of Heat Treatment of Steels by R.C. Sharma; 2. The, Heat Treating Source Book, ASM, 1986; 3. Heat Treatment of Metals by W.S. Owen (1963) (Institute for Metallurgists); 4. Engineering Physical Metallurgy and Heat Treatment by Y. Lakhtein (Mir Publisher); 5. Phase Transformations in Metals and Alloys by D.A. Porter and K.E. Easterling (Taylor and Francis).
MSE674	DESIGN OF SINTERED PRODUCTS	3-0-0--4	Factors affecting design materials and geometry: Specific design of products like permeable materials, structural parts, bearings and cutting tool materials: conditioning of metal powders to influence processing parameters: Product properties evaluation and their standardization.
MSE676	MATERIALS FAILURE: ANALYSIS AND PREVENTION	3-0-0-0-4	1. Introduction to Failure analysis and prevention: Concepts, root causes analysis, primary root causes, design deficiencies, material defects, manufacturing/installation defects, categoriesof failure, failure prevention (4 hours); 2. Failure Analysis: Processes, objectives, planning and preparation, practices and procedures. (3 hours); 3. Fracture modes, Ductile fracture of metallic. materials and their interpretations, factorsaffecting ductile brittle relationships. (3 hours); 4. Failure characteristics of Ceramics and Plastics (2 hours); 5. Brittle fracture in normally ductile metallic alloy, microstructural aspects of brittle fracture (2 hours); 6. Fatigue fracture, macroscopic and microscopic characteristics, statistical aspects of fatigue, Fatigue failure prediction and life assessment. (3 hours); 7. Wear Failures and Prevention (2 hours); 8. Corrosion related failures, Stress corrosion cracking, Hydrogen damage and embrittlement, Biological corrosion failures. (2 hours); 9. Elevated temperature failures, creep and stress rupture, metallurgical instabilities (2 hours); 10. Distortion failures and deformations (2 hours); 11. Structural life assessment methods, Nondestructive techniques. (2 hours);12. Tools and techniques in failure analysis: General Practices, Photography, Xrays, Metallographic techniques, Fractography, (4 hours); 13. Illustrative; Case studies of engineering failure; due to: improper processing practice, improper treatment procedure, improper design, unanticipated service conditions, improper material selection, improper service condition etc. Examples of component failures in (metals, ceramics and plastics. (8 hours). **Course Reference**: 1. Source book in failure analysis, American Society of Metals, Metals Park,

			Ohio, 1974; 2. Understanding how components fail, D.J Wulpi, ASM International, The Materials Information Society, 1999; 3. A.J. McEvily, Metal Failures: Mechanisms, Analysis, Prevention, Jolm Wiley and Sons,2002; 4. Practical engineering failure analysis, H.M. Tawancy, A. UlHamid and N.M. Abbas, Marcel Dekker, New York, 2004; 5. Failure analysis and prevention, Volume II, ASM Handbook, The Materials Information Society, 2002; 6. Failure analysis of engineering structures: Methodology and ase Histories, V.Ramachandran, A.C. Raghuram, R.V. Krishnan and S.K. Bhaumik , ASM International,2005.
MSE676A	MATERIALS FAILURE: ANALYSIS AND PREVENTION	3-0-0-0-9	1. Introduction to Failure analysis and prevention: Concepts, root causes analysis, primary rootcauses, design deficiencies, material defects, manufacturing/installation defects, categories of failure, failure prevention (4 hours); 2. Failure Analysis: Processes, objectives, planning and preparation, practices and procedures. (3 hours); 3. Fracture modes, Ductile fracture of metallic. materials and their interpretations, factors affecting ductile brittle relationships. (3 hours); 4. Failure characteristics of Ceramics and Plastics (2 hours); 5. Brittle fracture in normally ductile metallic alloy, microstructural aspects of brittle fracture (2 hours); 6. Fatigue fracture, macroscopic and microscopic characteristics, statistical aspects of fatigue, Fatigue failure prediction and life assessment. (3 hours); 7. Wear Failures and Prevention (2 hours); 8. Corrosion related failures, Stress corrosion cracking, Hydrogen damage and embrittlement, Biological corrosion failures. (2 hours); 9. Elevated temperature failures, creep and stress rupture, metallurgical instabilities (2 hours); 10. Distortion failures and deformations (2 hours); 11. Structural life assessment methods, Nondestructive techniques. (2 hours); 12. Tools and techniques in failure analysis: General Practices, Photography, Xrays, Metallographic techniques, Fractography, (4 hours); 13. Illustrative; Case studies of engineering failure; due to: improper processing practice, improper treatment procedure, improper design, unanticipated service conditions, improper material selection, improper service condition etc. **Course Reference**:1. Source book in failure analysis, American Society of Metals, Metals Park, Ohio, 1974; 2. Understanding how components fail , D.J Wulpi, ASM International, The Materials Information Society, 1999; 3. A.J. McEvily, Metal Failures: Mechanisms, Analysis, Prevention, Jolm Wiley and Sons,2002; 4. Practical engineering failure analysis, H.M. Tawancy, A. Ul Hamid and N.M. Abbas,Marcel Dekker, New York, 2004; 5.

			Failure analysis and prevention, Volume II , ASM Handbook, The Materials Information Society, 2002; 6. Failure analysis of engineering structures: Methodology and ase Histories, V.Ramachandran, A.C. Raghuram, R.V. Krishnan and S.K. Bhaumik , ASM International,2005.
MSE680	GRAIN BOUNDARY ENGINEERING	3-0-0--4	Grain boundary structure: Geometrical aspects, Degress of freedom, Principles governing grain shape and size their orientation. Theoretical formulations: Structurals unit model, Plane matching model, O Lattice model, Specialboundaries, CSL and DSC Lattice. Boundary energy and equilibria, Grain Boundarytypes, GB mobility and boundary solute interactions. GB structure and Properties: mechanical strength wear, creep magnetic, electrical etc. Simulation and modeling. Grain boundary engineering strategy: Deformation, thermomechanical treatment trace additions, Magnetic Field etc. GB descriptors: Connectivity, density junction distribution, Character distribution. Boundary Characterization Tools: Xray, EBSDOIM, CTEM, AEM, HRTEM, etc. Macrotexture analysis: Polefigure measurement, Xray diffraction, neutron diffraction methods. Micro texture analysis: Automated EBSD Kikuchi pattern, Houghs transform, SEMOIM based TEM based, Schemes for representation of Data Prospective applications: Superplasticity. Creep resistance, Corrosion Resistance, Superconductivity, Electronic ceramics etc.
MSE680A	GRAIN BOUNDARY ENGINEERING	3-0-0-0-9	Grain boundary structure: Geometrical aspects, Degress of freedom, Principles governing grain shape and size their orientation. Theoretical formulations: Structurals unit model, Plane matching model, O Lattice model, Special boundaries, CSL and DSC Lattice. Boundary energy and equilibria, Grain Boundary types, GB mobility and boundary solute interactions. GB structure and Properties: mechanical strength wear, creep magnetic, electrical etc. Simulation and modeling. Grain boundary engineering strategy: Deformation, thermo mechanical treatment trace additions, Magnetic Field etc. GB descriptors: Connectivity, density junction distribution, Character distribution. Boundary Characterization Tools: Xray, EBSDOIM, CTEM, AEM, HRTEM, etc. Macrotexture analysis: Polefigure measurement, Xray diffraction, neutron diffraction methods. Microtexture analysis: Automated EBSD Kikuchi pattern, Houghs transform, SEMOIM based TEM based, Schemes for representation of Data Prospective applications: Superplasticity. Creep resistance, Corrosion

			Resistance, Superconductivity, Electronic ceramics etc.
MSE681	SOLAR ENERGY TECHNOLOGIES AND MATERIALS	3-0-0-0-4	1. Introduction to the course. 2. Solar Spectrum. 3. Available solar energy technologies.4. Solar Thermal Energy Conversion. a. Fundamentals. b. Materials and Technologies.c. Applications. d. Present status. 5. Photovoltaic Devices and their fundamentals. 6. Solar Electricity Conversion or Solar Photovoltaics. a. Technologies _b. Materials, devices and issues, 1. First generation technologies Si based.u. Second generation technologies (low cost) thinfilms (aSi, CdTe, CIGS); solar concentrators. Third generation (high efficiency and low cost) Organic solar cells, multijunction, quantum dotsc. Device Characterizationd. Comparative Performance7. PV Processing with emphasis on migration from solar cells to modules to systems8. Present status and Future outlook **Course Reference**: 1. Thin Films Solar Cells, K.L. Chopra, McGraw Hill; 2. Physics and Technology of Solar Energy, H. P. Garg, M. Dayal, G. Furlan (1987) a. Volume 1: Solar Thermal Applicationsb. Volume II: Photovoltaic and Solar Energy Materials); 3. The Physics of Solar Cells (Properties of Semiconductor Materials), Jenny Nelson; 4. Third Generation Photovoltaics: Advanced Solar Energy Conversion (Springer Series inPhotonics) by M.A. Green; 5. Flexible Solar Cells by Mario Pagliaro, Giovanni Palmisano, and Rosaria Cirirninna (HardoverDec 10, 2008); 6. Physics of Solar Cells: From Basic Principles to Advanced Concepts (Physics Textbook) by Peter Warfel (Paperback April 13, 2009).
MSE681A	SOLAR ENERGY TECHNOLOGIES AND MATERIALS	3-0-0-0-9	1. Introduction to the course. 2. Solar Spectrum. 3. Available solar energy technologies.4. Solar Thermal Energy Conversion: a. Fundamentals. b. Materials and Technologies. c. Applications. d. Present status. 5. Photovoltaic Devices and their fundamentals. 6. Solar Electricity Conversion or Solar Photovoltaics: a. Technologies b. Materials, devices and issues, 1. First generation technologies Si based.u. Second generation technologies (low cost) thin films (aSi, CdTe, CIGS); solar concentrators.b. Third generation (high efficiency and low cost) Organic solar cells, multi junction, quantum dots c. Device Characterization d. Comparative Performance7. PV Processing with emphasis on migration from solar cells to modules to systems 8. Present status and Future outlook **Course Reference**: 1. Thin Films Solar Cells, K.L. Chopra, McGraw Hill; 2. Physics and Technology of Solar Energy, H. P. Garg, M. Dayal, G. Furlan

			(1987) a. Volume 1: Solar Thermal Applicationsb. Volume II: Photovoltaic and Solar Energy Materials) 3. The Physics of Solar Cells (Properties of Semiconductor Materials), Jenny Nelson4. Third Generation Photovoltaics: Advanced Solar Energy Conversion (Springer Series inPhotonics) by M.A. Green5. Flexible Solar Cells by Mario Pagliaro, Giovanni Palmisano, and Rosaria Cirirninna (HardoverDec 10, 2008)6. Physics of Solar Cells: From Basic Principles to Advanced Concepts (Physics Textbook) by Peter Warfel (Paperback April 13, 2009)
MSE682	COMPUTER SIMULATIONS IN MATERIALS SCIENCE	3-0-0-0-4	Objective of the course is to introduce students to the field of computational materials science. Thecourse commences with a brief discussion of basic physics and numerical methods, essential for therest of the course. The topics are divided into two major categories, classical and quantum mechanical simulation techniques. The first part focuses primarily on two popularly used methods, molecular dynamics and Monte Carlo; discussing basic theory, applications and examples related to materials science. The second part focuses on density functional based tight binding (DFTB) method. Basic applications, such as simple band structure calculation and geometry optimization and advanced topicssuch as electron transport calculations will be discussed. **Course Reference**: 1. Molecular dynamics simulation: Elementary methods, J. M. Haile (Wiley Professional); 2. The art of molecular dynamics simulation, D. C. Rapaport (Cambridge University Press); 3. Computer simulation of liquids, Allen and Tildesley (Oxford); 4. Computational materials science: an introduction, June Gunn Lee (CRC Press); 5. Electronic structure: basic theory and practical mehtods, Richard Martin (Cambridge).
MSE682A	COMPUTER SIMULATIONS IN MATERIALS SCIENCE	3-0-0-0-9	Objective of the course is to introduce students to the field of computational materials science. Thecourse commences with a brief discussion of basic physics and numerical methods, essential for therest of the course. The topics are divided into two major categories, classical and quantum mechanical simulation techniques. The first part focuses primarily on two popularly used methods, molecular dynamics and Monte Carlo; discussing basic theory, applications and examples related to materialsscience. The second part focuses on density functional based tight binding (DFTB) method. Basic applications, such as simple band structure calculation and geometry optimization and advanced topics such as electron transport calculations will be discussed. **Course Reference**: 1. Molecular dynamics

			simulation: Elementary methods, J. M. Haile (Wiley Professional); 2. The art of molecular dynamics simulation, D. C. Rapaport (Cambridge University Press); 3. Computer simulation of liquids, Allen and Tildesley (Oxford); .4. Computational materials science: an introduction, June Gunn Lee (CRC Press); 5. Electronic structure: basic theory and practical mehtods, Richard Martin (Cambridge).
MSE683	CRYSTALLOGRAPHIC TEXTURE & MECROSTRUCTURAL ENGINEERING	3-0-0-0-4	Introduction to crystallographic texture.Refresher on Xray diffraction: basic diffraction concepts, reciprocal space,instrumentation and geometry.Basics of neutron and synchrotron diffraction and comparison.Texture data representation: pole figures, inverse pole figures, orientation distribution function.Measurement of pole figures: experimental details, data processing, indexing Determination of Orientation Distribution Function and Misorientation.distribution Function: calculation techniques, different notations, 3D and 2D representation. Introduction to Electron Back Scatter Diffraction and microtexture: instrumentation, sample preparation, data acquisition and analysis. Mechanisms of evolution of texture during processing: solidification, phase transformation, deformation, annealing. Modelling texture evolution. Texture evolution and measurement in thin films. Grain boundary engineering: Principle, practice and applications. Material formability and texture. Functional properties and texture. **Course Reference**: 1. An Introduction to Texture in Metals; M. Heatherly, W. B. Hutchinson, Monograph no. 5, The Institution of Metallurgist London 1979; 2. Introduction to Texture Analysis: Macrotexture, Microtexture, and Orientation Mapping;0. Engler, V. Randle, CRC Press, 2010; 3. Texture and Anisotropy: Preferred Orientations in Polycrystals and their Effect on Materials Properties; U. F. Kocks, C. N. Tome, H.R. Wenk, Cambridge University Press, 2000; 4. Research publications on: Texture manipulation and control; Microstructural engineering; and Grain boundary engineering.
MSE683A	CRYSTALLOGRAPHIC TEXTURE & MECROSTRUCTURAL ENGINEERING	3-0-0-0-9	Introduction to crystallographic texture. Refresher on Xray diffraction: basic diffraction concepts, reciprocal space, instrumentation and geometry.Basics of neutron and synchrotron diffraction and comparison.Texture data representation: pole figures, inverse pole figures, orientation distribution function.Measurement of pole figures: experimental details, data processing, indexing Determination of Orientation Distribution Function and Misorientation Distribution Function: calculation techniques, different notations, 3D and

			2D representation. Introduction to Electron Back Scatter Diffraction and microtexture: instrumentation, sample preparation, data acquisition and analysis. Mechanisms of evolution of texture during processing: solidification, phase transformation, deformation, annealing. Modelling texture evolution. Texture evolution and measurement in thin films. Grain boundary engineering: Principle, practice and applications. Material formability and texture. Functional properties and texture. **Course Reference** : 1. An Introduction to Texture in Metals; M. Heatherly, W. B. Hutchinson, Monograph no. 5, The Institution of Metallurgist London 1979; 2. Introduction to Texture Analysis: Macrotexture, Microtexture, and Orientation Mapping;0. Engler, V. Randle, CRC Press, 2010; 3. Texture and Anisotropy: Preferred Orientations in Polycrystals and their Effect on Materials Properties; U. F. Kocks, C. N. Tome, H.R. Wenk, Cambridge University Press, 2000; 4. Research publications on: Texture manipulation and control; Microstructural engineering ; and Grain boundary engineering.
MSE685	THIN FILM PHYSICS & APPLICATIONS	3-0-0--4	Surface science; experimental techniques to study surfaces; kinetics of surface processes impingement of atoms, scattering, adsorption, sticking coefficient;Film nucleation and growth mechanisms, critical radius of nuclei, computer simulation of film growth, microstructure evolution; Film growth by evaporation,sputtering, chemical vapour deposition, atomic layer epitaxy, liquid phase epitaxy, solgel technique etc, Electrical, optical, magnetic and mechanical properties of thin films and their applications.
MSE686	SEMI CONDUCTOR DEVICES AND PROCESSING	3-0-0-0-4	contents: Review of semiconductor physics, carrier statistics, generation recombination and carrier transport. Devices: PN junctions, Schottky barrier diodes, MOS capacitors, field effect transistors. Planar technology and process flows for PN junctions and Schottky diodes. Oxidation, diffusion (oxidation enhanced diffusion, transient enhanced diffusion), ion implantation, deposition (chemical and physical vapour techniques), etching; Lithography; Device and process integration, with MOSFET as an example. **Course Reference**: 1. Nanomaterials, Nanotechnologies and Design: An Introduction to Engineers and Architects, D. Michael Ashby, Paulo Ferreira. Daniel L. Schodek, Butterworth Heinemann, 2009; 2. Handbook of Nanophase and Nanostructured Jaterials (in jour volume.). Ed: Z.L. Wang, Y. Liu, Z. Zhang, Kluwer Academic/Plenum Publishers, 2003; 3. Encyclopedia ofNanoscience

			and Nanotechnology, Ed.: Hari Singh Nalwa, American Scientific Publishers, 2004; 4. Handbook of Nanoceramics and their Based Nanodevices (Vol. 2) Edited by T eungYuenTyeng and Hari Singh NahFa, American Scientific Publishers.
MSE688	NANOMATERIALS: PROCESSING AND PROPERTIES	3-0-0--4	Definition and Classification of Nanomaterials, Fundamental Properties of various primary material classes (Metals, ceramics and Polymers), Size dependent properties and various characterization techniques of Nanomaterials, Synthesis/ Consolidation routes to produce Nanomaterials, Mechanochemical synthesisto produce nanosized precursor powders, Various routes to produce Nanometallic alloys (Rapid solidification), Challenges in processing bulk ceramic nanomaterials,Various densification routes for nanoceramics and nanoceramic composites, Processing structure properties of important bulk nanomaterials, Mechanical Properties, Thermal properties, Tribological Properties, Biological Properties(Biomedical applications), Applications of bulk nanomaterials, Critical issues related to understanding properties of nanomaterials.
MSE689	MULTI FUNCTIONAL OXIDES: THIN FILMS & DEVICE	3-0-0--4	Fundamentals of oxides: crystal structure, defect chemistry, and properties; focus on various material systems methods of fabrication e.g. solid statechemistry. Oxide thin films. polycrystalline versus epitaxial, main film deposition techniques: physical vapor and chemical deposition methods, PVD techniques:sputtering (fundamentals of glow discharge processes and film deposition RFand DC magnetron sputtering new approaches), laser ablation (basic science, applications, various approaches), science and technology of evaporation andmolecular beam epitaxy (MBE) Chemical processes basic and technological issuesof solgel chemical vapor deposition atomic layer deposition; PVD visa vischemical processes; issues related to epitaxy and case studies. Characterization methods: Structural techniques uses of X ray diffraction, atomic force microscopy scanning and transmission electron microscopy, spetroscopic methods; Electrical Measurements. Devices types of devices, fabrication: fundamentals and issues; Lithographic methods: conventional and next generation, FIB (fieldion) techniques, Nanofabrication: principles, processes and issues, Use of Scanning force microscopy in nanofabrication case studies.
MSE689A	MULTI FUNCTIONAL OXIDES: THIN FILMS & DEVICE	3-0-0-0-9	Fundamentals of oxides: crystal structure, defect chemistry, and properties; focus on various material systems methods of fabrication e.g. solid statechemistry. Oxide thin films. polycrystalline versus epitaxial, main film deposition techniques:

			physical vapor and chemical deposition methods, PVD techniques:sputtering (fundamentals of glow discharge processes and film deposition RFand DC magnetron sputtering new approaches), laser ablation (basic science,applications, various approaches), science and technology of evaporation and molecular beam epitaxy (MBE) Chemical processes basic and technological issuesof solgel chemical vapor deposition atomic layer deposition; PVD visa vischemical processes; issues related to epitaxy and case studies. Characterization methods: Structural techniques uses of X ray diffraction, atomic force microscopy scanning and transmission electron microscopy, spetroscopic methods; Electrical Measurements. Devices types of devices, fabrication: fundamentals and issues; Lithographic methods: conventional and next generation, FIB (fieldion) techniques, Nanofabrication: principles, processes and issues, Use of Scanning force microscopy in nanofabrication case studies.
MSE690	SEMINAR PARTICIPATION	0-0-0-0-0	Seminar Participation
MSE690A	SEMINAR PARTICIPATION	0-0-0-0-0	Seminar Participation
MSE691	SEMINAR PRESENTATION	0-0-0-0-0	Seminar Participation
MSE691A	SEMINAR PRESENTATION	0-0-0-0-0	Seminar Participation
MSE693	MATERIALS SCIENCE TECHNOLOGIES FOR APPLICATIONS IN LIFE SCIENCES	3-0-0-0-4	Introduction to integrating nanotechnology and materials science with life sciences: Introduction to various size regimes in life science and materials science Importance of integration of materials science and engineering with life sciencesProteins and DNA: Structure and properties : Cells organelles and building blocks of important molecules in cell (1) Protein structure, organization, functions with emphasis on antibodies and enzymes, regulation of enzyme activity, protein phosphorylation DNA: structure and function of DNA, DNA replication and repair Microfabrication techniques and soft lithography; Fundamentals of bioMEMS, microfluidic devices and Lab on chip devices Materials for MEMS Photolithography: (single crystal silicon, mask, oxide formation, resist application, baking, exposure, positive and negative resist, developing, etching. Etching: Dry Vs wet and isotropic Vs anisotropic, plasma (DC arc and RF), DRIE, wet bulk surface micromachining, 3D structure with sacrificial layer, LIGA Deposition: physical and chemical vapour deposition Soft fabrication: application of polymers in bioMEMS, microcontact printing, microtransfer

			moling, micromolding in capillaries, injection molding, hot embossing Biocompatibility : Definition of biocompatibility, host response to implanted device, in vivo and in vitro tests for biocompatibility Overview of immune system (innntate and adaptive immunity, cell mediated and humoral immunity), B cells, T cells, MHC **Course Reference**: 1. B. Alberts eta/., Essential Cell Biology. (Garland Publishing Inc., New York, ed. Third, 2009); 2. S. S. Saliterman, Fundamentals of bioMEMS and medical microdevices. (Wiley Interscience, Bellingham, 2005); 3. T.J. Kindt et. al., Kyby immunology. (W.H. Freeman, 6th edition 2007); 4. C. S. S. R. Kumar, Biofunctionalization of Nanomaterials. C. S. S. R. Kumar, Ed., Nanotechnologies for the life sciences (WileyVCH, Weinheim, 2006), vol. 1, pp. 366; 5. C. S. S. R. Kumar, Nanomaterials for biosensors. C. S. S. R. Kumar, Ed., Nanotechnologies for thelife sciences (WileyVCH, Weinheim, 2006), vol. 8; 6. C. S. S. R. Kumar, Nanosystem characterization tools in the life sciences. C. S. S. R. kumar, Ed., Nanotechnologies for the life sciences (WileyVCH, Weinheim, 2005), vol. 3.7. J. M. Anderson, Annu Rev of Matl Res, 31, 81 (2001)
MSE693A	MATERIALS SCIENCE TECHNOLOGIES FOR APPLICATIONS IN LIFE SCIENCES	3-0-0-0-9	Introduction to integrating nanotechnology and materials science with life sciences : Introduction to various size regimes in life science and materials science Importance of integration of materials science and engineering with life sciences Proteins and DNA: Structure and properties : Cells organelles and building blocks of important molecules in cell (1) Protein structure, organization, functions with emphasis on antibodies and enzymes, regulation of enzyme activity, protein phosphorylation DNA: structure and function of DNA, DNA replication and repair Microfabrication techniques and soft lithography; Fundamentals of bioMEMS, microfluidic devices and Labonchip devices Materials for MEMS Photolithography: (single crystal silicon, mask, oxide formation, resist application, baking, exposure, positive and negative resist, developing, etching). Etching: Dry Vs wet and isotropic Vs anisotropic, plasma (DC arc and RF), DRIE, wet bulk surface micromachining, 3D structure with sacrificial layer, LIGA Deposition: physical and chemical vapour deposition Soft fabrication: application of polymers in bioMEMS, microcontact printing, microtransfer moling, micromolding in capillaries, injection molding, hot embossing Biocompatibility : Definition of biocompatibility, host response to implanted device, in vivo and in vitro tests for biocompatibility Overview of immune system

			(innntate and adaptive immunity, cell mediated and humoral immunity), B cells, T cells, MHC **Course Reference**: 1.B. Alberts et. al., Essential Cell Biology. (Garland Publishing Inc., New York, ed. Third, 2009); 2. S. S. Saliterman, Fundamentals of bioMEMS and medical microdevices. (WileyInterscience, Bellingham, 2005); 3. T.J. Kindt eta/., Kyby immunology. (W.H. Freeman, 6th edition 2007); 4. C. S. S. R. Kumar, Biofunctionalization of Nanomaterials. C. S. S. R. Kumar, Ed., Nanotechnologiesfor the life sciences (WileyVCH, Weinheim, 2006), vol. 1, pp. 366; 5. C. S. S. R. Kumar, Nanomaterials for biosensors. C. S. S. R. Kumar, Ed., Nanotechnologies for thelife sciences (WileyVCH, Weinheim, 2006), vol. 8; 6. C. S. S. R. Kumar, Nanosystem characterization tools in the life sciences. C. S. S. R. kumar, Ed., Nanotechnologies for the life sciences (WileyVCH, Weinheim, 2005), vol. 3; 7. J. M. Anderson, Annu Rev of Matl Res, 31, 81 (2001).
MSE693N	MATERIALS SCIENCE TECHNOLOGIES FOR APPLICATIONS IN LIFE SCIENCES	3-0-0-0-4	Introduction to integrating nanotechnology and materials science with life sciences Introduction to various size regimes in life science and materials science. Importance of integration of materials science and engineering with life sciences Proteins and DNA: Structure and properties Cells organelles and building blocks of important molecules in cell (1) Protein structure, organization, functions with emphasis on antibodies and enzymes, regulation of enzyme activity, protein phosphorylation DNA: structure and function of DNA, DNA replication and repair Microfabrication techniques and soft lithography; Fundamentals of bioMEMS, microfluidic devices and Labonchip devices Materials for MEMS Photolithography: (single crystal silicon, mask, oxide formation, resist application, baking, exposure, positive and negative resist, developing, etching. Etching: Dry Vs wet and isotropic Vs anisotropic, plasma (DC arc and RF), DRIE, wet bulk surface micromachining, 3D structure with sacrificial layer, LIGA Deposition: physical and chemical vapour deposition Soft fabrication: application of polymers in bioMEMS, microcontact printing, microtransfer moling, micromolding in capillaries, injection molding, hot embossing Biocompatibility Definition of biocompatibility, host response to implanted device, in vivo and in vitro tests for biocompatibility Overview of immune system (innntate and adaptive immunity, cell mediated and humoral immunity), B cells, T cells, MHC Self assembly: Structure, Mechanism and Applications Difference between self assembly and self organization, example (organothiol molecules on gold substrate)

			Techniques for assembly: microcontact printing, dip pen nanolithography Layer by layer self assembly: methods, materials applications Application of multilayer biofilm and ultrathin coatings on medical implants. **Course Reference**: 1. B. Alberts et. al., Essential Cell Biology. (Garland Publishing Inc., New York, ed. Third, 2009); 2. S. S. Saliterman, Fundamentals of bioMEMS and medical microdevices. (WileyInterscience, Bellingham, 2005); 3. T.J. Kindt et. al., by immunology. (W.H. Freeman, 6th edition 2007); 4. C. S. S. R. Kumar, Biofunctionalization of Nanomaterials. C. S. S. R. Kumar, Ed., Nanotechnologies for the life sciences (WileyVCH, Weinheim, 2006), vol. 1, pp. 366; 5. C. S. S. R. Kumar, Nanomaterials for biosensors. C. S. S. R. Kumar, Ed., Nanotechnologies for the life sciences (WileyVCH, Weinheim, 2006), vol. 8.; 6. C. S. S. R. Kumar, Nanosystem characterization tools in the life sciences. C. S. S. R. kumar, Ed., Nanotechnologies for the life sciences (WileyVCH, Weinheim, 2005), vol. 3; 7. J. M. Anderson, Annu Rev of Matl Res, 31, 81 (2001).
MSE694	NANOSTRUCTURES AND NANOMATERIALS: CHARACTERIZATION AND PROPERTIES	3-0-0-0-4	Overview of Nanostructures and Nanomaterials: classification (Dimensionality, Morphology/ shape/structure of nanoentities, New Effect/ Phenomena). Crystalline nanomaterials and defects therein. Hybrid nanomaterials. Effect of size, structure, mechanism, and property on material performance. Multiscale hierarchical structures built out of nanosized building blocks (nano to macro). Eucledian, Hyperbolic and Spherical space structures. Nanostructures: Carbon Nanotubes, Fullerenes, Nanowires, Graphene, Quantum Dots. Thermodynamics of Nanomaterials. Configurational entropy and Gibbs free energy of nanocrystals. Wulff reconstruction. Surface reconstruction and reconfiguration. Adsorption and Absorption. **Course Reference**: 1.Nanomaterials, Nanotechnologies and Design: an Introduction to Engineers and Architects, D.Michael Ashby, Paulo Ferreira, Daniel L. Schodek, Butterworth Heinemann, 2009; 2. Handbook of Nanophase and Nanostructured Materials (in four volumes), Eds: Z.L. Wang, Y. Liu, Z.Zhang, Kluwer Academic/Plenum Publishers, 2003; 3. Encyclopedia of Nanoscience and Nanotechnology, Ed.: Hari Singh Nalwa, American Scientific Publishers, 2004; 4. Handbook of Nanoceramics and their Based Nanodevices (Vol. 2) Edited by TseungYuen Tseng andHari Singh Nalwa, American Scientific Publishers; 5. Introduction to Nanoscience, G.L. Hornyak, J.

			Dutta, H. F. Tibbals, A.K. Rao, CRC Press (2008).
MSE694A	NANOSTRUCTURES AND NANOMATERIALS: CHARACTERIZATION AND PROPERTIES	3-0-0-0-9	Overview of Nanostructures and Nanomaterials: classification (Dimensionality, Morphology/ shape/structure of nanoentities, New Effect/ Phenomena). Crystalline nanomaterials and defects therein. Hybrid nanomaterials. Effect of size, structure, mechanism, and property on material performanc. Multiscale hierarchical structures built out of nanosized building blocks (nano to macro). Eucledian, Hyperbolic and Spherical space structures. Nanostructures: Carbon Nanotubes, Fullerenes, Nanowires, Graphene, Quantum Dots. Thermodynamics of Nanomaterials. Configurational entropy and Gibbs free energy of nanocrystals. Wulff reconstruction. Surface reconstruction and reconfiguration. Adsorption and Absorption. **Course Reference**: 1. Nanomaterials, Nanotechnologies and Design: an Introduction to Engineers and Architects, D.Michael Ashby, Paulo Ferreira, Daniel L. Schodek, Butterworth Heinemann, 2009; 2. Handbook of Nanophase and Nano structured Materials (in four volumes), Eds: Z.L. Wang, Y. Liu, Z.Zhang, Kluwer Academic/Plenum Publishers, 2003; 3. Encyclopedia of Nanoscience and Nanotechnology, Ed.: Hari Singh Nalwa, American Scientific Publishers, 2004; 4. Handbook of Nanoceramics and their Based Nanodevices (Vol. 2) Edited by TseungYuen Tseng andHari Singh Nalwa, American Scientific Publishers; 5. Introduction to Nanoscience, G.L. Hornyak, J. Dutta, H. F. Tibbals, A.K. Rao, CRC Press (2008).
MSE695	DIFFRACTION AND SPECTROSCOPY TECHNIQUES FOR SURFACE CHARACTERISATION	3-0-0-0-4	DiiTraction and Spectroscopy Techniques for Surface Course Details: Importance of Smfacc Characterization. Present status sensitivity and resolution achievable. Diffraction Techniques: basic diffraction theory; Various Small Angle Xray Scattering techniques, and its applications; electron clift; action, LEED and RHEED. Properties of neutron radiation: neutron sources: Small angle neutron scattering; Illustrative analysis using diffraction techniques Spectroscopy: Basic principles of Spectroscopy. Principles of XPS, Instrumentation, XPSpatterns, Quantitative analysis. Chemical effect, Chemical shilL XPS imaging; Auger electron generation: Principle of AES. Chemical e1Tect, Quantitative analysis, Depth profiling, Applications; Static and Dynamic SlMS, Common modes of analysis, quantitative and Qualitative analysis; Case studies on the spectroscopic analysis of surfaces. **Course Reference**: l. Encycleopedia of Material’s Characterisation, C. R. Brunelle. C. A. Evans and

			S. Vilson, Butterworth Hennmann, 1992. Boston; 2. Characterisation of Materials Volume 2. Editor: E.N. Kaufmann, Wiley Interscience. 2003.New Jersey; 3. Surface Anctvsis kfethods in; Material's Science. D. J. oconnors, B.A. Sexton. and R. St. Smart, Springer (2003); 4. Materials Charocterization. published in 1986 as Volume l0 of the 10^{th} Edition Metals Handbook, ASM International. 1986 (Fifth printing 1998).
MSE698	SEMINAR PARTICIPATION	----	SEMINAR PARTICIPATION
MSE699	M.TECH THESIS	0-0-0-0-0	M. Tech. Thesis
MSE799	PH D THESIS	0-0-0-0-	Ph. D. Thesis
TA201A	MANUFACTURING PROCESSES I	1-0-3-0-6	Introduction to manufacturing: Evolution of manufacturing, Engineering materials classification, Evolution of manufacturing and its classifications. Engineering Materials: Structure of materials, Types of materials, Properties of materials, Microstructure property interrelationship. Casting/ Solidification: Classifications of casting processes, Patterns, Core making, Gating system, Solidification of pure metals and alloys, shrinkage, gas solubility, Riser design, Investment casting, Casting defects. Joining processes: Fusion welding: Arc (MMAW, SAW, SMAW), Gas welding and resistance welding, Fusion zone, Heat affected zone (HAZ), Brazing and Soldering, Solid state welding processes, Thermit welding. Deformation processes: Engineering stress strain curve, Effect of temperature on the workability, Extrusion (direct and indirect) Rolling classification, roll camber, defects, Forging (open and closeddie) Wire drawing, Defects, Sheetmetal forming. Powder metallurgy: Introduction, Powder production, Compaction, and Sintering, Engineering stress strain curve. Plastic injection molding: Flow forming of plastic components. Heat Treatment: Special techniques (Nonconventional techniques).
TA201N	INTRODUCTION TO MANUFACTURING PROCESSES	1-0-6-0-3	Introduction to Manufacturing, Historical perspective; Importance of manufacturing; Classification of manufacturing processes, Engineering materials,Casting, Fundamentals of casting, Sand casting, Permanent mold casting including pressure die casting, Shell, investment & centrifugal casting processes,Continuous casting, Casting defects, Metal Forming, Basic concepts of plastic deformation, Hot & cold working, Common bulk deformation processes (Rolling,Forging, Extrusion and Drawing), Common sheet metal forming processes,Machining, Chip formation and generation of machined surfaces, Tool geometry,tool material, tool wear and practical

			machining operations (turning, millingand drilling), Grinding processes, Finishing processes, Introduction to unconventional machining processes (EDM, ECM, UCM, CHM, LBM) etc., Welding & Other Joining Processes, Fundamentals of welding & classification of welding processes, Gas and arc welding, Brazing and soldering, Adhesive bonding, Mechanical fastening, Heat Treatment, Principles of heat treating; annealing, normalizing, hardening and tempering, Manufacturing of Polymer and Powder Products, Classification of polymers, Introduction to extrusion, injection molding,blow molding, compression and transfer molding , Green compacts from powders including slip casting of ceramics, Sintering, Modern Trends in Manufacturing.
TA201T	MANUFACTURING PROCESSES I		Introduction to manufacturing; Evolution of manufacturing; Importance ofdesign in manufacturing; Conventional material removal processes: chip formation, tooldynamics, practical machining and finishing operations; CNC machining; Unconventional machining; Introduction to microfabrication, layered manufacturing, and metrology. Specialized Infrastructure requirement: equipment. Unconventional machining demonstration

MATHEMATICS AND STATISTICS

MATHEMATICS AND SCIENTIFIC COMPUTING-<u>OLD TEMPLATE</u>

BS

Template No. BS-MTH-1

	SEMESTER							
	1st	2nd	3rd	4th	5th	6th	7th	8th
C	MTH101A [11]	MTH102A [11]	MTH204A [11]	MTH302A [09]	MTH305A [11]	MTH308A [11]	DE-1 [09]	HSS-5 (Level-2) [09]
O	PHY103A [11]	PHY102A [11]	MTH301A [11]	MTH421A [11]	MTH403A [11]	MTH424A [11]	DE-2 [09]	DE-3 [09]
U	CHM101A [03]	PHY101A [03]	COM200A [05]	HSS-2 (Level-1) [11]	ESO/SO-4 [09] (ESO207A)	HSS-4 (Level-2) [09]	MTH401A [09]	OE-4 [09]
R	ESC101A [14]	LIF101A [06]	ESO/SO-1 [~10]*	ESO/SO-2 [11] (MSO201A)	HSS-3 (Level-2) [09]	OE-2 [09]	MTH423 [11]	OE-5 [09]
S	ENG112A/HSS-1 (Level-1) [11]	CHM102A [08]	ESC201A [14]	ESO/SO-3 [~10]*	OE-1 (09]	OE-3 [09]	UGP-3 (MTH393A)/ DE/OE [09]	OE-6 [09]
E	PE101A [03]	PE102A [03]	TA201A [06]	TA202A [06]	MTH399A [02]	UGP-2 (MTH392A)/ DE/OE [09]	-	UGP-4 [09] (MTH394A) (extra credits)
S	-	TA101A [09]	-	-	UGP-1 [04] (MTH391A) (extra credits)	-		-
	53	51	57*	58*	51/55	58	47	45/54

<u>MINIMUM CREDIT REQUIREMENT FOR GRADUATION:</u>

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	108	Credits
Department Elective (DE)	:	27	Credits
Open Elective (OE)	:	54	Credits
UGP-2/UGP-3/DE/OE	:	18	Credits
*ESO/ SO	:	40	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	**420**	**Credits**

MATHEMATICS AND SCIENTIFIC COMPUTING-<u>NEW TEMPLATE</u>

BS

Template No. BS-MTH-1

	SEMESTER							
	1st	2nd	3rd	4th	5th	6th	7th	8th
C	MTH101A [11]	MTH102A [11]	MTH201A [11]	MTH204A [11]	MTH305A [11]	MTH.SCI.COMP-1 [10]	OE-3 [09]	HSS-5 (Level-2) [09]
O	PHY103A [11]	PHY102A [11]	MTH302A [11]	MTH301A [11]	MTH403A [11]	MTH421A [11]	DE-2 [09]	DE-3 [09]
U	CHM101A [03]	PHY101A [03]	COM200A [05]	HSS-2 (Level-1) [11]	ESO/SO-4 [09] (ESO207A)	HSS-4 (Level-2) [09]	MTH424A [11]	OE-4 [09]
R	ESC101A [14]	LIF101A [06]	ESO/SO-1 [~10]*	ESO/SO-2 [11] (MSO201A)	HSS-3 (Level-2) [09]	OE-1 [09]	MTH.SCI.COMP-2 [10]	OE-5 [09]
S	ENG112A/HSS-1 (Level-1) [11]	CHM102A [08]	ESC201A [14]	ESO/SO-3 [~10]*	DE-1 (09]	OE-2 [09]	UGP-3 (MTH393A)/ DE/OE [09]	OE-6 [09]
E	PE101A [03]	PE102A [03]	TA201A [06]	TA202A [06]	MTH399A [02]	UGP-2 (MTH392A)/ DE/OE [09]	-	UGP-4 [09] (MTH394A) (extra credits)
S	-	TA101A [09]	-	-	UGP-1 [04] (MTH391A) (extra credits)	-		-
	53	51	57*	60*	51/55	57	48	45/54

<u>MINIMUM CREDIT REQUIREMENT FOR GRADUATION:</u>

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	110	Credits
Department Elective (DE)	:	27	Credits
Open Elective (OE)	:	54	Credits
UGP-2/UGP-3/DE/OE	:	18	Credits
*ESO/ SO	:	40	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	**422**	**Credits**

OLD TEMPLATE

DOUBLE MAJOR		Template No. BS-MTH-4
	Odd Semester	Even Semester
	Pre-Requisites	
C	ESO207A [11]	MSO201A [11]
O		
U	Mandatory MTH Courses	
R	MTH204A [11]	MTH302A [09]
S	MTH301A [11]	MTH421A [11]
E	MTH305A [11]	MTH308A [11]
S	MTH403A [11]	MTH424A [11]
	MTH401A [09]	
	MTH423A [11]	
	64	42

TOTAL MANDATORY CREDITS FOR SECOND MAJOR IN MATHEMATICS & SCIENTIFIC COMPUTING: 106 CREDITS

REMARKS:

1) Upto 36 OE credits may be waived from the parent department BT/BS graduation requirements when they are used to fulfill requirements for the double major.

NEW TEMPLATE

DOUBLE MAJOR		Template No. BS-MTH-4
	Odd Semester	Even Semester
	Pre-Requisites	
C	ESO207A [11]	MSO201A [11]
O		
U	Mandatory MTH Courses	
R	MTH201A [11]	MTH204A [11]
S	MTH302A [11]	MTH301A [11]
E	MTH305A [11]	MTH SCI COMP-1 [10]
S	MTH403A [11]	MTH421A [11]
	MTH424A [11]	
	MTH SCI COMP-2 [10]	
	65	43

OLD TEMPLATE

BS-MS (PG Part – Category – A) *(from the same department)*			Template No. BS-MTH-2
	1st to 8th	9th	10th
C O U R S E S	COURSES AS DETAILED IN THE BS TEMPLATE	MS THESIS (MTH598A) [09]/ DE PG-1 [09]	MS THESIS (MTH599A) [09]/ DE PG-6 [09]
		DE PG-2 [09]	OE PG-1 [09]
		DE PG-3 [09]	OE PG-2 [09]
		DE PG-4 [09]	OE PG-3 [09]
		DE PG-5 [09]	OE PG-4 [09]
		45	45

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION:

PG Component : 90 Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ DUGC Convener.
2) Minimum credit requirement mentioned under the dual degree template is only for the MS part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
3) Upto 36 OE credits may be used from the BS minimum requirements to fulfil requirements for the BS-MS dual degree programme. These will be waived from the BS programme and counted towards PG requirements.

NEW TEMPLATE

BS-MS (PG Part – Category – A) *(from the same department)*			Template No. BS-MTH-2
	1st to 8th	9th	10th
C O U R S E S	COURSES AS DETAILED IN THE BS TEMPLATE	MS THESIS-1 [9+9]	MS THESIS-2 [9+9]
		DE PG-1 [09]	DE PG-3 [09]
		DE PG-2 [09]	DE PG-4 [09]
		OE PG-1/DE PG-5 [09]	OE PG-2/DE PG-6 [09]
		45	45

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION:

PG Component : 90 Credits

OLD TEMPLATE

BT/BS-MS (PG Part – Category – B) *(from other departments)*				Template No. BS-MTH-3
	UG Pre-Requisites		PG Requirements	
	Odd Semester	Even Semester	Odd Semester	Even Semester
COURSES	MTH204A [11]	MTH302A [09]	MS THESIS (MTH598A) [09]/ DE PG-1 [09]	MS THESIS (MTH599A) [09]/ DE PG-5 [09]
	MTH301A [11]	MTH421A [11]	DE PG-2 [09]	DE PG-6 [09]
	MTH305A [11]	MTH308A [11]	DE PG-3 [09]	
	MTH403A [11]	MTH424A [11]	DE PG-4 [09]	
	MTH401A [09]			
	MTH423A [11]			
	64	42	36	18

MINIMUM CREDIT REQUIREMENT IN MS PART FOR GRADUATION:

PG Component : 54 Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ DUGC Convener.
2) Minimum credit requirement mentioned under the dual degree template is only for the MS part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
3) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the dual degree programme. These will be waived from the parent department's BT/BS programme requirements and counted towards PG requirements.

NEW TEMPLATE

BT/BS-MS (PG Part – Category – B) *(from other departments)*				Template No. BS-MTH-3
	UG Pre-Requisites		PG Requirements	
	Odd Semester	Even Semester	Odd Semester	Even Semester
COURSES	MTH201A [11]	MTH204A [11]	MS THESIS-1 [9+9]	MS THESIS-2 [9+9]
	MTH302A [09]	MTH301A [11]	DE PG-1 [09]	DE PG-3 [09]
	MTH305A [11]	MTH SCI COMP-1 [10]	DE PG-2 [09]	DE PG-4 [09]
	MTH403A [11]	MTH421A [11]		
	MTH424A [11]			
	MTH SCI COMP-2 [10]			
	63	43	36	36

DEPARTMENT OF MTH

Courses ID	Course Title	Credits L-T-P-D-[C]	Content
MSO201A	PROBABILITY AND STATISTICS	3-1-0-0-11	Probability: Axiomatic definition, properties, conditional probability, Bayes rule and independence of events. Random variables, distribution function, probability mass and densityfunctions, expectation, moments, moment generating function, Chebyshev's inequality. Special distributions; Bernoulli, binomial, geometric, negative binomial, hypergeometric, Poisson, exponential, gamma, Weibull, beta, Cauchy, double exponential, normal. Reliability and hazardrate, reliability of series and parallel systems. Joint distributions, marginal and conditional distributions, moments, independence of random variables, covariance and correlation. Functionsof random variables. Weak Law of large numbers and Central limit theorems. Statistics: Descriptive statistics, graphical representation of the data, measures of location and variability. Population, sample, parameters. Point estimation; method of moments, maximum likelihood estimator, unbiasedness, consistency. Confidence intervals for mean, difference ofmeans, proportions. Testing of hypothesis; Null and alternate hypothesis, Neyman Pearson fundamental lemma, Tests for one sample and two sample problems for normal populations, testsfor proportions. **Course Reference**: 1. Introduction to Mathematical Statistics, by R V Hogg, A Craig and J W McKean; 2. An Introduction to Probability and Statistics by V.K. Rohatgi & A.K. Md. E. Saleh; 3. Introduction to Probability and

			Statistics by S. Milton & J.C. Arnold; 4. Introduction to Probability Theory and Statistical Inference by H.J. Larson; 5. Introduction to Probability and Statistics for Engineers and Scientists by S.M. Ross
MSO203	PARTIAL DIFFERENTIAL EQUATIONS	3-1-0-0-2	Sturm Liouville BVP: introduction, examples. Sturm Liouville BVP: orthogonal functions, Sturm Liouville expansions. Fourier series, convergence of Fourier series, Fourier series with arbitrary period. Fourier series: sine and cosine series, half range expansion. Fourier integrals, Fourier: Legendre series. Fourier Transform. Introduction to PDE, linear, nonlinear (semi linear, quasi linear) examples, order of PDEs. First order (linear, semi linear) PDEs, interpretation, method of characteristics. First order (linear, semi linear) PDEs, general solutions. First order quasi linear PDEs, interpretation, method of characteristics, general solutions. Classification of 2nd order PDEs, Canonical form: hyperbolic equations. Canonical form: parabolic equations, elliptic equations. Wave equations: DAlembertfs formula, Duhamelfs principle. Wave equations: solutions for initial boundary value problems. Heat equation: uniqueness and maximum principle, applications. Heat equation: solutions for initial boundary value problems. Laplace and Poisson equations: Uniqueness and maximum principle for Dirichlet problem. Laplace and Poisson equations: BVP in 2D (rectangular, polar). Laplace and Poisson equations: BVP in 3D (spherical, cylindrical) **Course Reference**: 1. E. Kreyszig. Advanced Engineering Mathematics. (8th Edition); 2. T. Amarnath. An Elementary Course in Partial Differential Equations.
MSO203B	PARTIAL DIFFERENTIAL EQUATIONS	3-1-0-0-6	Sturm Liouville BVP: introduction, examples. Sturm Liouville BVP: orthogonal functions, Sturm Liouville expansions. Fourier series, convergence of Fourier series, Fourier series with arbitrary period. Fourier series: sine and cosine series, half range expansion. Fourier integrals, Fourier: Legendre series. Fourier Transform. Introduction to PDE, linear, nonlinear (semi linear, quasi linear) examples, order of PDEs. First order (linear, semi linear) PDEs, interpretation, method of characteristics. First order (linear, semi linear) PDEs, general solutions. First order quasi linear PDEs, interpretation, method of characteristics, general solutions. Classification of 2^{nd} order PDEs, Canonical form: hyperbolic equations. Canonical form: parabolic equations, elliptic equations. Wave equations: DAlembertfs formula, Duhamelfs principle. Wave equations: solutions for initial boundary value problems. Heat equation: uniqueness and maximum principle, applications. Heat equation: solutions for initial boundary value problems. Laplace and Poisson equations: Uniqueness and maximum principle for Dirichlet problem. Laplace and Poisson equations: BVP in 2D (rectangular, polar). Laplace and Poisson equations: BVP in 3D (spherical, cylindrical) **Course Reference**: 1. E. Kreyszig. Advanced Engineering Mathematics. (8th Edition); 2. T. Amarnath. An Elementary Course in Partial Differential Equations.

MTH100	INTRODUCTION TO PROFESSION	2-0-0-0-0	Mathematical thought process: Proofs by construction, existence, specialization, induction, contradiction, Abstraction, Sets: Russels paradox, Axiom of Choice,Counting, Infinity, Continuum Hypothesis, Numbers:Real numbers, Cantors diagonalization arguments, Complex numbers, Fundamental theorem of algebra, Fermats last theorem, Goldbachs conjecture, Analysis: Existence ofnowhere differentiable functions, Zenos paradox infinite series, Geometry: Eulers theorem, Mobius strip, Trisection of an angle, Squaring a circle, Euclids parallel postulate, NonEuclidean geometries, Mathematical structures: Euclidean structure, Metric spaces, Hilbert spaces, Topology, Groups, Rings, Modules,Vector spaces, Algebraic geometry, Networks, Map coloring, Graphs, Computation: Iteration Approximations, Computability, Church Turing thesis
MTH101A	MATHEMATICS I	3-1-0-0-11	Real numbers, Sequences; Series; Power series, Limit, Continuity; Differentiability, Mean value theorems and applications; Linear Approximation, Newton and Picard method, Taylor's theorem (one variable), Approximation by polynomials, Critical points, convexity, Curve tracing, Riemann Integral, fundamental theorems of integral calculus, Improper integrals, Trapezoidal and SimpsonÆs rule; error bounds, Space coordinates, lines and planes, Polar coordinates, Graphs of polar equations; Cylinders, Quadric surfaces, Volume, Area, length; Continuity, Differentiability of vector functions, arc length; Curvature, torsion, Serret-Frenet formulas, Functions of two or more variables, partial derivatives Statement only, of Taylor's theorem and criteria for maxima/Minima/saddle points, Double, triple integrals, Jacobians; Surfaces, integrals, Vector Calculus, Green, Gauss, Stokes Theorems.,
MTH101N	MATHEMATICS I	3-1-0-1-4	Real numbers, Sequences; Series; Power series, Limit, Continuity; Differentiability, Mean value theorems and applications; Linear Approximation, Newton and Picard method, Taylors theorem (one variable), Approximation by polynomials, Critical points, convexity, Curve tracing, Riemann Integral, fundamental theorems of integral calculus, Improper integrals, Trapezoidal and Simpsons rule; error bounds, Space coordinates, lines and planes, Polar coordinates, Graphs of polar equations; Cylinders, Quadric surfaces, Volume, Area, length; Continuity, Differentiability of vector functions, arc length; Curvature, torsion, SerretFrenet formulas, Functions of two or more variables, partial derivatives Statement only, of Taylors theorem and criteria for maxima/Minima/saddle points, Double, triple integrals, Jacobians; Surfaces, integrals, Vector Calculus, Green, Gauss, Stokes Theorems.,
MTH102A	MATHEMATICS - II	3-1-0-0-11	Matrices: matrix operations (Addition, Scalar Multiplication, Multiplication,Transpose, Adjoint and their properties; Special types of matrices (Null, Identity,Diagonal, Triangular, Symmetric, Skew Symmetric, Hermitian, Skew Hermitian,Orthogonal, Unitary, Normal), Solution of the matrix Equation Ax = b; Rowreduced Echelon form,

			Determinants and their properties, Vector Space $R^n(R)$; Subspaces; Linear Dependence/Independence; Basis; Standard Basis of R^n; Dimension; Coordinates with respect to a basis; Complementary Subspaces;Standard Inner product; Norm; GramSchmidt Orthogonalization Process; Generalization to the vector space $C^n(C)$, Linear Transformation from R^n toR^m (motivation, X* AX); Image of a basis identifies the linear transformation; Range Space and Rank; Null Space and Nullity; Matrix Representation of a linear transformation; Structure of the solutions of the matrix equation Ax=b; Linear Operators on Rn and their representation as square matrices; Similar Matrices and linear operators; Invertible linear operators; Inverse of a non-singular matrix; Cramers method to solve the matrix equation Ax=b; Eigenvalues and eigenvectors of a linear operator; Characteristic Equation; Bounds on eigenvalues;Diagonalizability of a linear operator; Properties of eigenvalues and eigenvectors of Hermitian, skewHermitian, Unitary, and Normal matrices (including symmetric, skewsymmetric, and orthogonal matrices), Implication of diagonalaizability ofthe matrix $A + A^T$ in the real quadratic form $X^T AX$;
MTH102N	MATHEMATICS - II	3-1-0-1-4	Matrices: matrix operations (Addition, Scalar Multiplication, Multiplication,Transpose, Adjoint and their properties; Special types of matrices (Null, Identity,Diagonal, Triangular, Symmetric, Skew-Symmetric, Hermitian, SkewHermitian,Orthogonal, Unitary, Normal), Solution of the matrix Equation Ax=b; Row-reduced-Echelon form, Determinants and their properties, Vector Space $R^n(R)$;Subspaces; Linear Dependence/Independence; Basis; Standard Basis of Rn;Dimension; Coordinates with respect to a basis; Complementary Subspaces;Standard Inner product; Norm; GramSchmidt Orthogonalization Process;Generalization to the vector space Cn(C), Linear Transformation from R^n to R^m (motivation, X* AX); Image of a basis identifies the linear transformation;Range Space and Rank; Null Space and Nullity; Matrix Representation of a linear transformation; Structure of the solutions of the matrix equation Ax=b; LinearOperators on R^n and their representation as square matrices; Similar Matrices and linear operators; Invertible linear operators; Inverse of a non-singular matrix; Cramers method to solve the matrix equation Ax=b; Eigenvalues and eigenvectors of a linear operator; Characteristic Equation; Bounds on eigenvalues; Diagonalizability of a linear operator; Properties of eigenvalues and eigenvectorsof Hermitian, skewHermitian, Unitary, and Normal matrices (including symmetric, skewsymmetric, and orthogonal matrices), Implication of diagonalaizability of the matrix $A + A^T$ in the real quadratic form $X^T AX$;
MTH201	LINEAR ALGEBRA	3-1-0-0-4	Fields and linear equations. Vector spaces. Linear transformations and projections, Determinants. Elementary canonical forms: diagonalization, triangulation, primary decomposition etc. Secondary decomposition theorem,

			Rational canonical forms, Jordan canonical forms and some applications. Inner product spaces, Selfadjoint, Unitary and normal operators, Orthogonal projections. Bilinearforms, Symmetric, Skewsymmetric, Positive and semipositive forms etc.
MTH201A	A FIRST COURSE IN LINEAR ALGEBRA	3-1-0-0-11	Fields and linear equations. Vector spaces. Linear transformations and projections, Determinants. Elementary canonical forms: diagonalization, triangulation, primary decomposition etc. Secondary decomposition theorem, Rational canonicalforms, Jordan canonical forms and some applications. Inner product spaces, Selfadjoint, Unitary and normal operators, Orthogonal projections. Bilinearforms, Symmetric, Skewsymmetric, Positive and semipositive forms etc.
MTH201N	LINEAR ALGEBRA	3-1-0--4	Fields and linear equations. Vector spaces. Linear transformations and projections, Determinants. Elementary canonical forms: diagonalization, triangulation, primary decomposition etc. Secondary decomposition theorem, Rational canonicalforms, Jordan canonical forms and some applications. Inner product spaces, Self adjoint, Unitary and normal operators, Orthogonal projections. Bilinear forms, Symmetric, Skewsymmetric, Positive and semipositive forms etc.
MTH202	DISCRETE MATHEMATICS	3-1-0-0-4	Permutations and combinations and basic definitions. Generating functions. Polya's enumeration theory. Recurrence relations. Principle of inclusion and exclusion. Balanced incomplete block design. Difference sets. System of distinct representatives. Orthogonal Latin squares. Hadamard matrices.
MTH203N	MATHEMATICS - III	3-1-0-1-4	Introduction and Motivation to Differential Equations, First Order ODE f (x, y) geometrical Interpretation of solution, Equations reducible to separable form, Exact Equations, Integrating factor, Linear Equations, Orthogonal trajectories, Picards Theorem for IVP (without proof) and Picards iteration method, EulerMethod, Improved Eulers Method, Elementary types of equations. F (x, y, y); not solved for derivative, Second Order Linear differential equations: fundamental system of solutions and general solution of homogeneous equation. Use of Known solution to find another, Existence and uniqueness of solutionof IVP, Wronskian and general solution of nonhomogeneous equations. EulerCauchy Equation, extensions of the results to higher order linear equations,Power Series Method application to Legendre Eqn., Legendre Polynomials,Frobenious Method, Bessel equation, Properties of Bessel functions, SturmLiouville BVPs, Orthogonal functions, Sturm comparision Theorem, Laplace transform, Fourier Series and Integrals, Introduction to PDE, basic concepts,Linear and quasilinear first order PDE, second order PDE and classification ofsecond order semilinear PDE (Canonical form), D Alemberts formula and Duhamels principle for one dimensional wave equation, Laplaces and Poissons equations, Maximum principle with

			application, Fourier Method for IBV problem for wave and heat equation, rectangular region, Fourier method for Laplaces equation in three dimensions, Numerical methods for Laplaces and Poissons equations.
MTH204	ALGEBRA I	3-1-0-0-4	Some set theoretic notions: Relations, Functions, Partitions, Division algorithm. Various binary operations and examples. Groups and their properties, Subgroups, Cyclic groups and its subgroups, Group of integers and its properties, Fundamental theorem of arithmetic. Properties of subgroups, Lagrange theorem. Normal subgroupand Quotient group, Homomorphism, Isomorphism theorems. Symmetric group, Cyclic decomposition of a permutation, Alternating group. Group action, Class equation, Cauchy's theorem, Sylow theorems and their applications. Ring and its properties, Characteristic of a ring, Integral domain, Field, Division ring. Ideals and Quotient ring, Homomorphism, Isomorphism theorems. Polynomial ring, Unique factorization domain, Principal Ideal domain, Euclidean domain, Gaussian ring. **Course Reference**: 1. Contemporary Abstract Algebra, Joseph A Gallian (Narosa Publishing House, NewDelhi, 1998); 2. Algebra, Michael Artin (Prentice Hall of India, New Delhi, 1994); 3. Abstract Algebra, John B Fraleigh (Narosa Publishing House, New Delhi, 1988); 4. Abstract Algebra, David S Dummit and Richard M Foote (John Wiley & Sons, NewDelhi, 1999).
MTH204A	ABSTRACT ALGEBRA	3-1-0-0-11	Some set theoretic notions: Relations, Functions, Partitions, Division algorithm. Various binary operations and examples. Groups and their properties, Subgroups, Cyclic groups and its subgroups, Group of integers and its properties, Fundamental theorem of arithmetic. Properties of subgroups, Lagrange theorem. Normal subgroupand Quotient group, Homomorphism, Isomorphism theorems. Symmetric group, Cyclic decomposition of a permutation, Alternating group. Group action, Class equation, Cauchy's theorem, Sylow theorems and their applications. Ring and its properties, Characteristic of a ring, Integral domain, Field, Division ring. Ideals and Quotient ring, Homomorphism, Isomorphism theorems. Polynomial ring, Unique factorization domain, Principal Ideal domain, Euclidean domain, Gaussian ring. **Course Reference**: 1. Contemporary Abstract Algebra, Joseph A Gallian (Narosa Publishing House, NewDelhi, 1998); 2. Algebra, Michael Artin (Prentice Hall of India, New Delhi, 1994); 3. Abstract Algebra, John B Fraleigh (Narosa Publishing House, New Delhi, 1988); 4. Abstract Algebra, David S Dummit and Richard M Foote (John Wiley & Sons, NewDelhi, 1999).
MTH215	NUMBER THEORY	3-1-0--4	Divisibility, Primes, Congruences, Residue systems, Primitive roots; Quadratic reciprocity, some arithmetic functions, Farey fractions, Continued fractions, Some Diophantine equations, Bertrands postulate and the partition function.

MTH215A	NUMBER THEORY	3-1-0-0-11	Divisibility, Primes, Congruences, Residue systems, Primitive roots; Quadratic reciprocity, some arithmetic functions, Farey fractions, Continued fractions, some Diophantine equations, Bertrands postulate and the partition function.
MTH300	BASIC STRUCTURE OF MATHEMATICS	3-1-0--4	Finite and Infinite Sets: Finite sets, Countable sets, Uncountable sets. Groupsand Symmetry: Groups, Subgroups, Lagrange theorem, Normal subgroups, Quotient groups, Group actions, Homomorphisms, Group of symmetry rigidmotion group, finite subgroups of the rotation group, symmetric group. MetricSpaces: Open sets, Closed sets, Sequences, Continuity, Complete metric spaces, Contraction principle and applications, Connectedness and compactness. Fractals: Metric space of fractals and its completeness, Iterated function systems, Attractor, Algorithms to generate fractals. Topology of Surfaces: Eulers theorem, Construction of surfaces by identification: Torus, mobius strip, Klein bottle.
MTH301	ANALYSIS - I	3-1-0-0-4	Real Number system: Completeness property. Countable and Uncountable.Metric Spaces: Metric spaces, Examples: lp, C [a; b]; Limit, Open sets, Convergenceof a sequence, Closed sets, Continuity. Completeness: Complete metric space, Nested set theorem, Baire category theorem, An application. Compactness: Totally bounded, Characterizations of compactness, Finite intersection property, Continuous functionson compact sets, Uniform continuity. Connectedness: Characterizations of connectedness, Continuous functions on connected sets, Path connected. Riemann integration: Denition and existence of integral, Fundamental theorem of calculus, Set of measure zero, Cantor set, Characterization of integrable functions. Convergence of sequence andseries of functions: Pointwise and uniform convergence of functions, Series of functions, Power series, Dini’s theorem, Ascoli’s theorem, Continuous function which is no where dierentiable, Weierstrass approximation theorem. **Course Reference**: 1. N.L. Carothers, Real Analysis; 2. R. R. Goldberg, Methods of Real Analysis; 3. W. Rudin, Principles of Mathematical Analysis.
MTH301A	ANALYSIS- I	3-1-0-0-11	Real Number system: Completeness property. Countable and Uncountable.Metric Spaces: Metric spaces, Examples: lp, C [a; b]; Limit, Open sets, Convergence of a sequence, Closed sets, Continuity. Completeness: Complete metric space, Nested set theorem, Baire category theorem, An application. Compactness: Totally bounded, Characterizations of compactness, Finite intersection property, Continuous functionson compact sets, Uniform continuity. Connectedness: Characterizations of connectedness, Continuous functions on connected sets, Path connected. Riemann integration: Denition and existence of integral, Fundamental theorem of calculus, Set of measure zero, Cantor set, Characterization of integrable functions. Convergence of sequence andseries of functions: Pointwise and uniform convergence of functions, Series of

			functions, Power series, Dini's theorem, Ascoli's theorem, Continuous function which is no where differentiable, Weierstrass approximation theorem. **Course Reference**: 1. N.L. Carothers, Real Analysis; 2. R. R. Goldberg, Methods of Real Analysis; 3. W. Rudin, Principles of Mathematical Analysis.
MTH302	MATHEMATICAL LOGIC	3-1-0-0-4	Formal theories, Consequence and deduction. Propositional Calculus: Syntax, Semantics, Applications; Axiomatic approach, Soundness, Consistency, Completeness. Other proof techniques: Sequent calculus, Tableaux. Boolean Algebras: Properties, Stone's theorem. Completeness of propositional calculus with respect to the classof Boolean algebras. Classical rst order theories: Syntax, Semantics; Axiomatic approach, Soundness; Sequent calculus, Tableaux. Equality, examples of rst order theories with equality. Consistency, Completeness (sketch), Elementary model theory, Decidability. Godel's incompleteness theorems: sketch. **Course Reference**: 1. R. Cori and D. Lascar, Mathematical Logic, Oxford, 2001; 2. A. Margaris, First Order Mathematical Logic, Dover, 1990; 3. J. Goubalt Larrecq and J. Mackie, Proof Theory and Automated Deduction, Kluwer,1997.
MTH302A	SET THEORY & LOGIC	3-0-0-0-9	Formal theories, Consequence and deduction. Propositional Calculus: Syntax, Semantics, Applications; Axiomatic approach, Soundness, Consistency, Completeness. Other proof techniques: Sequent calculus, Tableaux. Boolean Algebras: Properties, Stone's theorem. Completeness of propositional calculus with respect to the classof Boolean algebras. Classical rst order theories: Syntax, Semantics; Axiomatic approach, Soundness; Sequent calculus, Tableaux. Equality, examples of rst order theories with equality. Consistency, Completeness (sketch), Elementary model theory, Decidability.Godel's incompleteness theorems: sketch. **Course Reference**: 1. R. Cori and D. Lascar, Mathematical Logic, Oxford, 2001; 2. A. Margaris, First Order Mathematical Logic, Dover, 1990; 3. J. Goubalt Larrecq and J. Mackie, Proof Theory and Automated Deduction, Kluwer,1997.
MTH304	TOPOLOGY	3-1-0-0-4	Topological spaces, Basis for a topology, The order topology, Subspace topology, Closed sets. Countability axioms, Limit points, Convergence of nets in topological spaces, Continuous functions, The product topology, Metric topology, Quotient topology. Connected spaces, Connected sets in R, Components and path components, Compact spaces, Compactness in metric spaces, Local compactness, One-point compactification. Separation axioms, Uryshons lemma, Uryshons metrization theorem, Tietz extension theorem. The Tychonoff theorem, Completely regular spaces, Stone Czech compactification.
MTH304A	TOPOLOGY	3-1-0-0-11	Topological spaces, Basis for a topology, The order topology, Subspace topology, Closed sets. Countability

			axioms, Limit points, Convergence of nets in topological spaces, Continuous functions, The product topology, Metric topology, Quotient topology. Connected spaces, Connected sets in R, Components and path components, Compact spaces, Compactness in metric spaces, Local compactness, One-point compactification. Separation axioms, Uryshons lemma, Uryshons metrization theorem, Tietz extension theorem. The Tychonoff theorem, Completely regular spaces, Stone Czech compactification.
MTH305	SEVERAL VARIABLE CALCULUS & DEFFERENTIAL GEOMETRY	3-1-0-0-4	Diferentiation: Denition and examples, Mean value inequality, Tangent planes to level sets of functions; Implicit mapping theorem, Inverse mapping theoremand applications; Taylor's theorem and applications. Curves: Denition and examples, Regular curves, Plane curves, Curvature of plane curves, Isoperimetric inequality forplane curves; Space curves, Frenet Serret formula for space curves; Local existence theorem curves. Surfaces: Denition and examples; Tangent planes, Maps between surfaces; First fundamental and second fundamental forms; Curvature of surface; Hilbert's theorem for compact surfaces; Gauss theorema Egregium. **Course Reference**: 1. Spivak, Calculus on manifolds, Springer; 2. Kumaresan, Dierential geometry and Lie groups, TRIM Series; 3. M P do Carmo, Dierential geometry of curves and surfaces, Prentice Hall; 4. A Pressley, Elementary dierential geometry, Springer India
MTH305A	SEVERAL VARIABLE CALCULUS & DEFFERENTIAL GEOMETRY	3-1-0-0-11	Diferentiation: Denition and examples, Mean value inequality, Tangent planes to level sets of functions; Implicit mapping theorem, Inverse mapping theorem and applications; Taylor's theorem and applications. Curves: Denition and examples, Regular curves, Plane curves, Curvature of plane curves, Isoperimetric inequality for plane curves; Space curves, Frenet Serret formula for space curves; Local existence theoremcurves. Surfaces: Denition and examples; Tangent planes, Maps between surfaces; First fundamental and second fundamental forms; Curvature of surface; Hilbert's theorem for compact surfaces; Gauss theorema Egregium. **Course Reference**: 1. Spivak, Calculus on manifolds, Springer; 2. Kumaresan, Dierential geometry and Lie groups, TRIM Series; 3. M P do Carmo, Dierential geometry of curves and surfaces, Prentice Hall; 4. A Pressley, Elementary dierential geometry, Springer India
MTH306	LINEAR PROGRAMMING AND EXTENSIONS	3-1-0-0-4	Linear Models: Formulation and Examples, Basic Polyhedral Theory Convexity,Extreme points, Supporting hyperplanes etc, Simplex Algorithm Algebraic and Geometrical approaches, Artificial variable technique, Duality Theory: Fundamentalt heorem, Dual simplex method, Primaldual method, Sensitivity Analysis, Bounded Variable L.P.P. Transportation Problems: Models and Algorithms, Network Flows:Shortest path Problem, Max Flow problem and Mincost Flow problem, Dynamic Programming: Principle of optimality, Discrete and continuous models.

MTH306A	LINEAR PROGRAMMING AND EXTENSIONS	3-1-0-0-11	Linear Models: Formulation and Examples, Basic Polyhedral Theory Convexity, Extreme points, Supporting hyperplanes etc, Simplex Algorithm Algebraic and Geometrical approaches, Artificial variable technique, Duality Theory: Fundamental theorem, Dual simplex method, Primaldual method, Sensitivity Analysis, Bounded Variable L.P.P. Transportation Problems: Models and Algorithms, Network Flows: Shortest path Problem, Max Flow problem and Mincost Flow problem, Dynamic Programming: Principle of optimality, Discrete and continuous models.
MTH308	PRINCIPLES OF NUMERICAL COMPUTATION	3-1-0-0-4	Root nding problem: Methods and analysis; Interpolation: Methodsand analysis; Approximation: Least squares and minimax approximation; Numerical differentiation; Numerical integration: Methods and analysis; Numerical solution of linear systems; Numerical eigenvalue and eigenvector problem; Singular value decomposition. **Course Reference**: 1. Elementary Numerical Analysis, an algorithmic approach, S.D. Conte and Carl DeBoor; 2. An Introduction to Numerical Analysis, Kendall E Atkinson; 3. Numerical Methods for Scientic and Engineering Computations, M.K. Jain, S.R.K. Iyengar, R.K. Jain; 4. Introduction to Scientic Computing, C.F. Van Loan
MTH308A	PRINCIPLES OF NUMERICAL COMPUTATIONS	3-1-0-0-11	Root nding problem: Methods and analysis; Interpolation: Methodsand analysis; Approximation: Least squares and minimax approximation; Numerical differentiation; Numerical integration: Methods and analysis; Numerical solution of linear systems; Numerical eigenvalue and eigenvector problem; Singular value decomposition. **Course Reference**: 1. Elementary Numerical Analysis, an algorithmic approach, S.D. Conte and Carl DeBoor; 2. An Introduction to Numerical Analysis, Kendall E Atkinson; 3. Numerical Methods for Scientic and Engineering Computations, M.K. Jain, S.R.K. Iyengar, R.K. Jain; 4. Introduction to Scientic Computing, C.F. Van Loan
MTH311	PROBABILITY THEORY - I	3-1-0-0-4	Sets and set operations, Sample space, Sigma fields, Measurable spaces, Events. Measure spaces, Caratheodorys extension theorem, Construction of measures, Product spaces, Product measures. Probability measurer and its properties. Independence of events. Measurable functions, Approximations through simple functions, Random variables. Induced measures and probability distribution functions: discrete, continuous and absolutely continuous, one to one correspondence with induced probability measure, decomposition. Independence of random variables, Borel Cantelli lemmas. Integration in measure spaces, Expectation, Fatous lemma, Monotone convergence and dominated convergence theorems, Uniform integrability, Markov, Chebyshev, Cauchy Schwarz, Minkowski, Holder, Jensen and Lyapunov inequalities. Absolute continuity of measures, RandonNikodym theorem, Conditional expectation, Conditional probability measures. Fubinis theorem, Convolution. Functions of random variables, Jacobian theorem.

MTH311A	PROBABILITY THEORY - I	3-1-0-0-11	Sets and set operations, Sample space, Sigma fields, Measurable spaces, Events. Measure spaces, Caratheodorys extension theorem, Construction of measures, Product spaces, Product measures. Probability measurer and its properties. Independence of events. Measurable functions, Approximations through simple functions, Random variables. Induced measures and probability distribution functions: discrete, continuous and absolutely continuous, one to onecorrespondence with induced probability measure, decomposition. Independence of random variables, Borel Cantelli lemmas. Integration in measure spaces, Expectation, Fatous lemma, Monotone convergence and dominated convergence theorems, Uniform integrability, Markov, Chebyshev, Cauchy Schwarz, Minkowski, Holder, Jensen and Lyapunov inequalities. Absolute continuity of measures, Randon Nikodym theorem, Conditional expectation, Conditional probability measures. Fubinis theorem, Convolution. Functions of random variables, Jacobian theorem.
MTH391A	UG PROJECT (UGP-I)	0-0-0-0-4	UG PROJECT (UGPI)
MTH392A	UNDER GRADUATE PROJECT II	0-0-9-0-9	UG PROJECT (UGPII)
MTH393A	UG PROJECT (UGP-III)	3-0-0-0-9	UG PROJECT (UGPIII)
MTH399A	TECHNICAL COMMUNICATIO N SKILLS	0-0-0-2-2	Technical Communication
MTH401	THEORY OF COMPUTATION	3-1-0-0-4	Regular languages, Deterministic and nondeterministic nite automata, Closure properties, Languages that are and are not regular, State minimizationin deterministic nite automata. Contextfree languages, Closure properties, Parsetrees, Languages that are and are not contextfree, Pushdown automata. Turing machines, Turing computability, ChurchTuring thesis, Halting problem, Some undecidable problems. Computational complexity, Classes P and NP, NPcompleteness, Examples of NPcomplete problems. **Course Reference**: 1. H.R. Lewis and C.H. Papadimitriou: Elements of the Theory of Computation, PrenticeHall, 1998; 2. J.E. Hopcroft, R. Motwani, J.D. Ullman, Introduction to Automata Theory, Languages, and Computation, Pearson Education, 2001.
MTH401A	THEORY OF COMPUTATION	3-0-0-0-9	Regular languages, Deterministic and nondeterministic nite automata, Closure properties, Languages that are and are not regular, State minimizationin deterministic nite automata. Context free languages, Closure properties, Parsetrees, Languages that are and are not contextfree, Pushdown automata. Turing machines, Turing computability, Church Turing thesis, Halting problem, Some undecidable problems. Computational complexity, Classes P and NP, NP completeness, Examples of NP complete

			problems. **Course Reference**: 1. H.R. Lewis and C.H. Papadimitriou: Elements of the Theory of Computation, PrenticeHall, 1998; 2. J.E. Hopcroft, R. Motwani, J.D. Ullman, Introduction to Automata Theory, Languages, and Computation, Pearson Education, 2001.
MTH403	COMPLEX ANALYSIS	3-1-0-0-4	Topology on C, Convergence and continuity. Cauchy Riemann equation, Elementary Functions. Power series: Convergence, Exponential, Trigonometric functions. Integration along curves, Cauchy Goursat Theorem, Cauchy’s theorem for disc, Evaluation of some integrals, Cauchy integral formula, Liouville theorem and fundamental theorem of Algebra, Identity theorem, Morera’s theorem. Zeros and poles, Residue theorem, Evaluation of some integrals. Riemann theorem on removable singularities, Essential singularities, Casorati Weierstrass theorem. Riemann sphere, Argument principle, Rouche’s theorem, Open mapping theorem, Maximum modulus principle, Cauchy’s theorem for simply connected domain, Analyticity of complex logarithm. Harmonic functions, Poisson integral formula, Characterization of harmonic functions through MVP.Fractional linear transformation, Schwartz lemma, Pick’s lemma, Automorphisms of discand upper half plane. Montel theorem, Riemann mapping theorem. **Course Reference**: 1. Stein and Shakarchi: Complex Analysis, Princeton Lect. in Analysis; 2. Gamelin: Complex Analysis, Springer
MTH403A	COMPLEX ANALYSIS	3-1-0-0-11	Topology on C, Convergence and continuity. Cauchy Riemann equation, Elementary Functions. Power series: Convergence, Exponential, Trigonometric functions. Integration along curves, CauchyGoursat Theorem, Cauchy’s theorem for disc, Evaluation of some integrals, Cauchy integral formula, Liouville theorem and fundamental theorem of Algebra, Identity theorem, Morera’s theorem. Zeros and poles, Residue theorem, Evaluation of some integrals. Riemann theorem on removable singularities, Essential singularities, Casorati Weierstrass theorem. Riemann sphere, Argument principle, Rouche’s theorem, Open mapping theorem, Maximum modulus principle, Cauch’s theorem for simply connected domain, Analyticity of complex logarithm. Harmonic functions, Poisson integral formula, Characterization of harmonic functions through MVP.Fractional linear transformation, Schwartz lemma, Pick’s lemma, Automorphisms of discand upper half plane. Montel theorem, Riemann mapping theorem. **Course Reference** :1. Stein and Shakarchi: Complex Analysis, Princeton Lect. in Analysis; 2. Gamelin: Complex Analysis, Springer
MTH404	ANALYSIS II	3-1-0-0-4	Lebesgue measure on Rn: Introduction, outer measure, measurable sets, Lebesgue measure, regularity properties, a nonmeasurable set, measurable functions, Egoroffs theorem, Lusins theorem. Lebesgue integration: Simple functions, Lebesgue integral of a bounded function over a set of finite measure, bounded convergence theorem,

			integral of nonnegative functions, FatousLemma, monotone convergence theorem, the general Lebesgue integral, Lebesgue convergence theorem, change of variable formula. Differentiation and integration: Functions of bounded variation, differentiation of an integral, absolutely continuity, Lpspaces: The Minkowskis inequality and Hlders inequality, completeness of Lp, denseness results in Lp. Fourier series: Definition of Fourierseries, formulation of convergence problems, The L2 theory of Fourier series, convergence of Fourier series.
MTH404A	ANALYSIS II	3-1-0-0-11	Lebesgue measure on Rn: Introduction, outer measure, measurable sets, Lebesgue measure, regularity properties, a nonmeasurable set, measurable functions, Egoroffs theorem, Lusins theorem. Lebesgue integration: Simple functions, Lebesgue integral of a bounded function over a set of finite measure, bounded convergence theorem, integral of nonnegative functions, FatousLemma, monotone convergence theorem, the general Lebesgue integral, Lebesgue convergence theorem, change of variable formula. Differentiation and integration: Functions of bounded variation, differentiation of an integral, absolutely continuity, Lpspaces: The Minkowskis inequality and Hlders inequality, completeness of Lp, denseness results in Lp. Fourier series: Definition of Fourier series, formulation of convergence problems, The L2 theory of Fourier series, convergence of Fourier series.
MTH405	FUNCTIONAL ANALYSIS	3-1-0-0-4	Fundamentals of normed linear spaces: Normed linear spaces, Riesz lemma, characterization of finite dimensional spaces, Banach spaces. Bounded linear maps on a normed- linear spaces: Examples, linear map on finite dimensional spaces, finite dimensional spaces are isomorphic, operator norm. HahnBanach theorems: Geometric and extension forms and their applications. Three main theorems on Banach spaces: Uniform boundedness principle, divergence of Fourier series, closed graph theorem, projection, open mapping theorem, comparable norms. Dual spaces and adjoint of an operator: Duals of classical spaces, weak and weak* convergence, Banach Alaoglu theorem, adjoint of anoperator. Hilbert spaces: Inner product spaces, orthonormal set, GramSchmidt orthonormalization, Bessels inequality, Orthonormal basis, Separable Hilbertspaces. Projection and Riesz representation theorem: Orthonormal complements, orthogonal projections, projection theorem, Riesz representation theorem. Bounded operators on Hilbert spaces: Adjoint, normal, unitary, self adjointoperators, compact operators, eigen values, eigen vectors, Banach algebras. Spectral theorem: Spectral theorem for compact self adjoint operators, statement of spectral theorem for bounded self adjoint operators.
MTH405A	FUNCTIONAL ANALYSIS	3-1-0-0-11	Fundamentals of normed linear spaces: Normed linear spaces, Riesz lemma, characterization of finite dimensional spaces, Banach spaces. Bounded linearmaps on a normed- linear spaces: Examples, linear map on finite dimensional

			spaces, finite dimensional spaces are isomorphic, operator norm. HahnBanach theorems: Geometric and extension forms and their applications. Three main theorems on Banach spaces: Uniform boundedness principle, divergence of Fourier series, closed graph theorem, projection, open mapping theorem, comparable norms. Dual spaces and adjoint of an operator: Duals of classical spaces, weak and weak* convergence, Banach Alaoglu theorem, adjoint of anoperator. Hilbert spaces: Inner product spaces, orthonormal set, GramSchmidt orthonormalization, Bessels inequality, Orthonormal basis, Separable Hilbert spaces. Projection and Riesz representation theorem: Orthonormal complements, orthogonal projections, projection theorem, Riesz representation theorem. Bounded operators on Hilbert spaces: Adjoint, normal, unitary, self adjoint operators, compact operators, eigen values, eigen vectors, Banach algebras. Spectral theorem: Spectral theorem for compact self adjoint operators, statement of spectral theorem for bounded self adjoint operators.
MTH409	COMPUTER PROGRAMMING AND DATA STRUCTURES	2-1-1-0-4	Fortran 77: Integer and real operations, logic and complex operations, Control statements, Do statement, arrays subroutines and functions. Introduction todata structures in C Programming Language; Arrays: linear, Multidimensional, Records, Pointers, Stacks, queues, Linked Lists; Singly linked lists, doubled linked lists, circular linked lists, Application of Linked Lists; Polynomial addition, sparse matrices, Trees: binary trees, redblack trees, Hash tables. Some discussion about data structures in F90F95 with examples.
MTH409A	COMPUTER PROGRAMMING AND DATA STRUCTURES	2-1-1-0-9	Fortran 77: Integer and real operations, logic and complex operations, Controlstatements, Do statement, arrays subroutines and functions. Introduction todata structures in C Programming Language; Arrays: linear, Multidimensional, Records, Pointers, Stacks, queues, Linked Lists; Singly linked lists, doubleedlinked lists, circular linked lists, Application of Linked Lists; Polynomial addition, sparse matrices, Trees: binary trees, redblack trees, Hash tables. somediscussion about data structures in F90F95 with examples. 21-JUL-2014
MTH411	PROBABILITY THEORY II	3-1-0-0-4	Tight families of probability distributions, Convergence of probability distribution functions, Hellys theorem, Helly Bray theorem, Skorohods fundamental theorem, Scheffes theorem; Weak convergence, Uniform integrability and convergence of expectations. Characteristic functions, Inversion formula, Levy continuity theorem, Expansion of characteristic functions, Polyas theorem, Bochners theorem. Moments and uniqueness of the probability distribution, Frechet Shohat theorem. Central limit theorems: Lindeberg Levy, Lyapunov and Lindeberg Feller. Various modes of convergence and the interrelations. Strong and weak laws of large numbers.
MTH412	APPLIED STOCHASTIC	3-1-0-0-4	Definition and classification of general stochastic processes. Markov Chains: definition, transition probability matrices,

	PROCESS		classification of states, limiting properties. Markov Chains with Discrete State Space: Poisson process, birthand death processes. Renewal Process: renewal equation, mean renewal time, stopping time. Markov Process with Continuous State Space: Introduction to Brownian motion.
MTH412A	APPLIED STOCHASTIC PROCESS	3-1-0-0-11	Definition and classification of general stochastic processes. Markov Chains: definition, transition probability matrices, classification of states, limiting properties. Markov Chains with Discrete State Space: Poisson process, birthand death processes. Renewal Process: renewal equation, mean renewal time, stopping time. Markov Process with Continuous State Space: Introduction to Brownian motion. 22-MAR-2014
MTH413	REAL AND COMPLEX ANALYSIS	3-1-0--4	Real and complex numbers; Open, closed and compact sets in Rn; Limits andcontinuity; Differentiation and Integration; Sequences and series; Sequences and series of functions; Complex integration.
MTH413A	REAL AND COMPLEX ANALYSIS	3-1-0-0-11	Real and complex numbers; Open, closed and compact sets in Rn; Limits andcontinuity; Differentiation and Integration; Sequences and series; Sequences and series of functions; Complex integration.
MTH415	MATRIX THEORY AND LINEAR ESTIMATION	3-1-0--4	Review of finite dimensional vector spaces (Null space and nullity), Linear dependence and independence, Matrix algebra, Rank of a Matrix, Inverse ofa nonsingular matrix. Hermite canonical forms, Generalised inverses, MoorePenrose inverse, solution of linear equations, Projection and orthogonal projection matrices, Idempotent matrices. Real quadratic forms, reduction of pair of real symmetric matrices, Singular value decomposition. extrema of a quadratic forms, Vector and matrix differentiation. Least squares theory and Gauss Mark off theorem, Cochran's theorem and distribution of quadratic forms, testof single linear hypothesis and more than one hypothesis, ANOVA table, Confidence interval and regions, Power of Ftest. Multiple comparisons and simultaneous confidence intervals.
MTH415A	MATRIX THEORY AND LINEAR ESTIMATION	3-1-0-0-11	Review of finite dimensional vector spaces (Null space and nullity), Linear dependence and independence, Matrix algebra, Rank of a Matrix, Inverse ofa nonsingular matrix. Hermite canonical forms, Generalised inverses, MoorePenrose inverse, solution of linear equations, Projection and orthogonal projection matrices, Idempotent matrices. Real quadratic forms, reduction of pair of real symmetric matrices, Singular value decomposition. Extrema of a quadratic forms, Vector and matrix differentiation. Least squares theory and Gauss Markoff theorem, Cochran's theorem and distribution of quadratic forms, test of single linear hypothesis and more than one hypothesis, ANOVA table, Confidence interval and regions, Power of Ftest. Multiple comparisons and simultaneous confidence intervals.
MTH416	REGRESSION ANALYSIS	3-1-0-0-4	Simple and multiple linear regression, Polynomial regression and orthogonal polynomials, Test of significance

			and confidence intervals for parameters. Residuals and their analysis for test of departure from the assumptions suchas fitness of model, normality, homogeneity of variances, detection of outliers, Influential observations, Power transformation of dependent and independent variables. Problem of multicollinearity, ridge regression and principal component regression, subset selection of explanatory variables, Mallow's Cp statistic. Nonlinear regression, different methods for estimation (Least squares and Maximum likelihood), Asymptotic properties of estimators. Generalised Linear Models (GLIM), Analysis of binary and grouped data using logistic and log linear models.
MTH416A	REGRESSION ANALYSIS	3-1-0-0-11	Simple and multiple linear regression, Polynomial regression and orthogonal polynomials, Test of significance and confidence intervals for parameters. Residuals and their analysis for test of departure from the assumptions suchas fitness of model, normality, homogeneity of variances, detection of outliers, Influential observations, Power transformation of dependent and independent variables. Problem of multicollinearity, ridge regression and principal component regression, subset selection of explanatory variables, Mallow's Cp statistic. Nonlinear regression, different methods for estimation (Least squares and Maximum likelihood), Asymptotic properties of estimators. Generalised Linear Models (GLIM), Analysis of binary and grouped data using logistic and log linearmodels.
MTH417	SAMPLING THEORY	3-1-0-0-4	Principles of sample surveys; Simple, Stratified and unequal probability sampling with and without replacement; ratio, product and regression method of estimation; systematic sampling; cluster and subsampling with equal unequal sizes; double sampling; sources of errors in surveys.
MTH417A	SAMPLING THEORY	3-1-0-0-11	Principles of sample surveys; Simple, Stratified and unequal probability samplingwith and without replacement; ratio, product and regression method of estimation; systematic sampling; cluster and subsampling with equal unequal sizes; double sampling; sources of errors in surveys.
MTH418	INFERENCE I	3-1-0--4	Parametric models, parametrs, random sample and its likelihood, statistic and its sampling distributions, problems of inference. Examples from standard discrete and continuous models such as Bernoulli, Binomial, Poisson, Negative Binomial, Normal, Exponential, Gamma, Weibull, Pareto etc. Concept of sufficiency, minimal sufficiency, Neyman factorization criterion, Fisher information, exponential families. Maximum likelihood estimators, method of moment estimators, percentile estimators, least squares estimators, minimum mean squares estimators, uniformly minimum variance unbiased estimators, RaoBlackwell theorem, CramerRao lower bond, different examples. Statistical Hyptheses simple and composite, statistical tests, critical regions, TypeI andTypeII errors, size and power of a test, Neyman Pearson lemma and its different applications. Most powerful test, uniformly most

			powerful test, unbiased testand uniformly most unbiased test. Likelihood ratio test. Interval estimation, confidence intervals, construction of confidence intervals, shortest expectedlength confidence interval, most accurate one sided confidence interval and itsrelation to UMP test.
MTH418A	INFERENCE -I	3-1-0-0-11	Parametric models, parametrs, random sample and its likelihood, statistic andits sampling distributions, problems of inference. Examples from standard discrete and continuous models such as Bernoulli, Binomial, Poisson, Negative Binomial, Normal, Exponential, Gamma, Weibull, Pareto etc. Concept of sufficiency, minimal sufficiency, Neyman factorization criterion, Fisher information, exponential families. Maximum likelihood estimators, method of moment estimators, percentile estimators, least squares estimators, minimum mean squares estimators, uniformly minimum variance unbiased estimators, RaoBlackwell theorem, CramerRao lower bond, different examples. Statistical Hyptheses simple and composite, statistical tests, critical regions, TypeI and TypeII errors, size and power of a test, Neyman Pearson lemma and its different applications. Most powerful test, uniformly most powerful test, unbiased testand uniformly most unbiased test. Likelihood ratio test. Interval estimation, confidence intervals, construction of confidence intervals, shortest expected length confidence interval, most accurate one sided confidence interval and its relation to UMP test.
MTH421	ORDINARY DIFFERENTIAL EQUATIONS	3-1-0-0-4	Introduction to ODE; Existence and uniqueness of solution; Continuity and dierentiability of solution w.r.t. initial condition and parameters; Generaltheory of linear dierential equations; Methods of solving nonhomogeneous linear equations; CauchyEuler equation; Linear equations with periodic coecients; System of lineardierential equations; Stability theory for system of linear dierential equations; StrumLiouville boundary value problems, Oscillation theory; Green's function. **Course Reference**: 1. Martin Brown, Dierential Equations and Their Applications, Springer, 1992; 2. S. L. Ross, Introduction to Ordinary Dierential Equations, Wiley, 1980; 3. Deo, Lakshmikantham, Raghavendra, Textbook of Ordinary Dierential Equations, Tata McGraw Hill, 1997; 4. C. Y. Lin, Theory and Examples of Ordinary Dierential Equations, World Scientic,2011.
MTH421A	ORDINARY DIFFERENTIAL EQUATIONS	3-1-0-0-11	Introduction to ODE; Existence and uniqueness of solution; Continuityand dierentiability of solution w.r.t. initial condition and parameters; General theory of linear dierential equations; Methods of solving nonhomogeneous linear equations; CauchyEuler equation; Linear equations with periodic coecients; System of lineardierential equations; Stability theory for system of linear dierential equations; StrumLiouville boundary value problems, Oscillation theory; Green's function. **Course Reference**: 1. Martin Brown, Dierential Equations and Their Applications, Springer, 1992; 2. S. L. Ross, Introduction to Ordinary Dierential Equations, Wiley, 1980;

			3. Deo, Lakshmikantham, Raghavendra, Textbook of Ordinary Dierential Equations, Tata McGraw Hill, 1997; 4. C. Y. Lin, Theory and Examples of Ordinary Dierential Equations, World Scientic,2011.
MTH423	INTRODUCTION TO CONTINUUM MACHANICS	3-1-0-0-4	Fundamental concepts; Introduction to Cartesian tensors; Stress tensors and equilibrium equations; Theory of strain and rate of deformation tensor; Conservation laws and basic equations; Linear Elasticity {Hooke's law, plane elasticity, Airy's stress principle, Torsion and bending; Fluid mechanics} Incompressible inviscid flow, Incompressible viscous flow, Introduction to boundary layer theory **Course Reference**: 1. Introduction to Continuum Mechanics {M. Lai, D. Rubin, E. Krempl}; 2. Continuum Mechanics for Engineers {G. T. Mase and G. E. Mase}; 3. Elementary fluid mechanics {D. J. Acheson}; 4. Fluid Mechanics {P K Kundu and I M Cohen}; 5. Mathematical Theory of Elasticity {Sokolniko}
MTH423A	INTRODUCTION TO CONTINUUM MACHANICS	3-1-0-0-11	Fundamental concepts; Introduction to Cartesian tensors; Stress tensors and equilibrium equations; Theory of strain and rate of deformation tensor; Conservation laws and basic equations; Linear Elasticity {Hook's law, plane elasticity, Airy's stress principle, Torsion and bending}; Fluid mechanics} Incompressible inviscid flow, Incompressible viscous flow, Introduction to boundary layer theory} **Course Reference**: 1. Introduction to Continuum Mechanics {M. Lai, D. Rubin, E. Krempl}; 2. Continuum Mechanics for Engineers {G. T. Mase and G. E. Mase; 3. Elementary fluid mechanics D. J. Acheson}; 4. Fluid Mechanics {P K Kundu and I M Cohen}; 5. Mathematical Theory of Elasticity {Sokolniko}
MTH424	PARTIAL DIFFERENTIAL EQUATIONS	3-1-0-0-4	Introduction to PDEs, First order quasilinear and nonlinear equations; Higher order equations and classications; Solution of wave equations, Duhamel's principle and applications; Existence and uniqueness of solutions; BVPs for Laplace's andPoisson's equations, Green's function, Maximum principle for the Laplace equation; Heatequation, Maximum principle for the heat equation, Uniqueness of solutions of IVPs forheat conduction equation. **Course Reference**: 1. Robert C. McOwen: Partial Dierential Equations, Pearson Education Inc; 2. Alen Jerey: Applied Partial Dierential Equations, Academic Press; 3. Ervin Kreyszig: Advanced Engineering Mathematics, John Wiley & Sons; 4. T. Amarnath, An Elementary Course in Partial Dierential Equations, Narosa Publications.
MTH424A	PARTIAL DIFFERENTIAL EQUATIONS	3-1-0-0-11	Introduction to PDEs, First order quasilinear and nonlinear equations; Higher order equations and classications; Solution of wave equations, Duhamel's principleand applications; Existence and uniqueness of solutions; BVPs for Laplace's and Poisson's equations, Green's function, Maximum principle for the Laplace equation; Heat equation, Maximum principle for the heat equation, Uniqueness of solutions of IVPs forheat conduction equation. **Course Reference**: 1. Robert C. McOwen: Partial Dierential

			Equations, Pearson Education Inc; 2. Alen Jerey: Applied Partial Dierential Equations, Academic Press; 3. Ervin Kreyszig: Advanced Engineering Mathematics, John Wiley & Sons; 4. T. Amarnath, An Elementary Course in Partial Dierential Equations, Narosa Publications.
MTH428	MATHEMATICAL METHODS	3-1-0-0-4	Multiple Integral Theorems and their Applications: Greens theorem, Stokes theorem and Gauss divergence theorem. Integral Transforms: Fourier, Fouriersine/cosine and Hankel Transforms with their inverse transforms (properties, convolution theorem and application to solve differential equation). Perturbation Methods: Perturbation theory, Regular perturbation theory, Singular perturbation theory, Asymptotic matching. Calculus of Variation: Introduction, Variational problem with functionals containing first order derivatives and Euler equations. Functionals containing higher order derivatives and several independent variables. Variational problem with moving boundaries. Boundaries with constraints. Higher order necessary conditions, Weiretrass function, Legendres and Jacobiscondition. Existence of solutions of variational problems. RayleighRitz method, statement of Ekelands variational principle; Self adjoint, normal and unitary operators; Banach algebras.
MTH428A	MATHEMATICAL METHODS	3-1-0-0-11	Multiple Integral Theorems and their Applications: Greens theorem, Stokes theorem and Gauss divergence theorem. Integral Transforms: Fourier, Fouriersine/cosine and Hankel Transforms with their inverse transforms (properties, convolution theorem and application to solve differential equation). Perturbation Methods: Perturbation theory, Regular perturbation theory, Singular perturbation theory, Asymptotic matching. Calculus of Variation: Introduction, Variational problem with functionals containing first order derivatives and Euler equations. Functionals containing higher order derivatives and several independent variables. Variational problem with moving boundaries. Boundaries with constraints. Higher order necessary conditions, Weiretrass function, Legendres and Jacobis condition. Existence of solutions of variational problems. RayleighRitz method, statement of Ekelands variational principle; Self adjoint, normal and unitary operators; Banach algebras.
MTH506	OPTIMIZATION	3-1-0-0-4	Optimization Problem: various examples, Characterization of optimality and constrained optimal problems, Convex sets and convex functions and their properties, Nonlinear programming theory KuhnTucker conditions, Lagranges theory, Duality theory, Search techniques one variable and several variables, Pontryagins maximum principle and its applications, Dynamic programming and its applications.
MTH511	STATISTICAL SIMULATION AND DATA ANALYSIS	3-1-0-0-4	Simulation of random variables from discrete, continuous, multivariate distributions and stochastic processes, MonteCarlo methods. Regression analysis, scatter plot, residual analysis. Computer Intensive Inference Methods JackKnife, Bootstrap, cross validation, Monte Carlo methods and permutation tests. Graphical representation of multivariate data, Cluster analysis, Principal component

			analysis for dimension reduction.
MTH511A	STATISTICAL SIMULATION AND DATA ANALYSIS	3-1-0-0-11	Simulation of random variables from discrete, continuous, multivariate distributions and stochastic processes, MonteCarlo methods. Regression analysis, scatterplot, residual analysis. Computer Intensive Inference Methods JackKnife, Bootstrap, cross validation, Monte Carlo methods and permutation tests. Graphical representation of multivariate data, Cluster analysis, Principal component analysis for dimension reduction.
MTH512	FOUNDATIONS OF MATHEMATICAL FINANCE	3-1-0-0-4	Fundamentals of the financial markets, meaning of notions like asset portfolio derivatives (example: Futures, options forwwards etc.) Binomial asset pricing model under no arbitrage condition single period model, multiperiod model. Risk neutral probabilities, martingales in the discreate framework, risk neutral valuation of European and American ooptions under noarbitrage condition in the binomial framework. Introduction to continuous time models. Basic notions of probability theory onan infinite sample space. Change of measure and the Radon Nikodym derivative. Random walk and Brownian motion, Ito intergral and Ito formula BlackScholes formula for pricing, a European call option. Markowitz mean variance portfolio optimization problem. Single period andmulti period model, Capital asset pricing model, outlines of the measures ofrisk, Value at Risk (VaR) and Conditional Value at Risk (CVaR).
MTH512A	FOUNDATIONS OF MATHEMATICAL FINANCE	3-1-0-0-11	Fundamentals of the financial markets, meaning of notions like asset portfolio derivatives (example: Futures, options forwards etc.) Binomial asset pricing model under no arbitrage condition single period model, multiperiod model. riskneutral probabilities, martingales in the discreate framework, risk neutral valuation of European and American ooptions under no arbitrage condition in the binomial framework. Introduction to continuous time models. Basic notions of probability theory on an infinite sample space. Change of measure and the Radon Nikodym derivative. Random walk and Brownian motion, Ito intergral and Ito formula Black Scholes formula for pricing a European call option. Markowitz mean variance portfolio optimization problem. Single period and multi period model, Capital asset pricing model, outlines of the measures ofrisk, Value at Risk (VaR) and Conditional Value at Risk (CVaR)
MTH513	ANALYSIS OF VARIANCE	3-1-0--4	Analysis of completely randomized design, randomized block design, Latin squares design; Splitplot; factorials with total and partial confounding, twoway nonorthogonal experiment, BIBD, PBIBD; Analysis of covariance, missing plot techniques; First and second order response surface designs.
MTH513A	ANALYSIS OF VARIANCE	3-1-0-0-11	Analysis of completely randomized design, randomized block design, Latinsquares design; Splitplot; factorials with total and partial confounding, twoway nonorthogonal experiment, BIBD, PBIBD; Analysis of covariance, missing plot techniques; First and second order response surface designs.

MTH514	MULTIVARIATE ANALYSIS	3-1-0--4	Multivariate normal distribution, assessing normality, Wishart and Hotellings T2; Comparisons of several multivariate means, MANOVA; multivariate linear regression models; principal components, factor analysis; canonical correlations; discrimination & classification.
MTH514A	MULTIVARIATE ANALYSIS	3-1-0-0-11	Multivariate normal distribution, assessing normality, Wishart and HotellingsT2; Comparisons of several multivariate means, MANOVA; multivariate linear regression models; principal components, factor analysis; canonical correlations; discrimination & classification.
MTH515	INFERENCE - II	3-1-0--4	Group families, the principle of equivariance, location family, scale family, location scale family. Minimum risk equivariance estimators, risk functions, admissibility, prior distribution, posterior distribution, geometric interpretationfor finite parameter space, Bayes estimators, limit of Bayes estimators, minimax estimators and their relations. Review of convergence in probability andconvergence in distributions. Consistency results of the mle's, and the mme's. Asymptotic relative efficiency. Consistent and Asymptotic Normal (CAN) estimators, Invariance of CAN estimators under different transformations. CAN estimatorsobtained by moments and MLE methods in one parameter xponential familyand multiparameter exponential family. Sequential Probability Ratio Tests andits applications in different practical problems. Invariant test and unbiased tests, Likelihood ratio test and its asymptotic distributions, Wald test, Rao's scoretest, Pearson c2 test for goodness of fit. Large sample tests and confidence intervals based on CAN estimators. Consistency of large sample tests and asymptotic powers of large sample tests.
MTH515A	INFERENCE - II	3-1-0-0-11	Group families, the principle of equivariance, location family, scale family, location scale family. Minimum risk equivariance estimators, risk functions, admissibility, prior distribution, posterior distribution, geometric interpretationfor finite parameter space, Bayes estimators, limit of Bayes estimators, minimax estimators and their relations. Review of convergence in probability and convergence in distributions. Consistency results of the mle's, and the mme's. Asymptotic relative efficiency. Consistent and Asymptotic Normal (CAN) estimators, Invariance of CAN estimators under different transformations. CAN estimators obtained by moments and MLE methods in one parameter exponential family and multi parameter exponential family. Sequential Probability Ratio Tests andits applications in different practical problems. Invariant test and unbiased tests, Likelihood ratio test and its asymptotic distributions, Wald test, Rao's score test, Pearson C2 test for goodness of fit. Large sample tests and confidence intervals based on CAN estimators. Consistency of large sample tests and asymptotic powers of large sample tests.
MTH516	NON-PARAMETRIC INFERENCE	3-1-0--4	Order statistics, Run tests, Goodness of fit tests, rank order statistics, signtest and signed rank test. general two sample problems, Mann Whitney test, Linear rank tests for location

			and scale problem, ksample problem, Measures of association, Power and asymptotic relative efficiency, Concepts of jackknifing, Bootstrap methods.
MTH516A	NON-PARAMETRIC INFERENCE	3-1-0-0-11	Order statistics, Run tests, Goodness of fit tests, rank order statistics, signtest and signed rank test. general twosample problems, MannWhitney test, Linear rank tests for location and scale problem, ksample problem, Measures of association, Power and asymptotic relative efficiency, Concepts of jackknifing, Bootstrap methods.
MTH517	TIME SERIES ANALYSIS	3-1-0-0-4	Linear stationary processes, AR, MA, ARMA and ARIMA; identification, estimationof the models; forecasting time series regression; Fourier analysis, spectralrepresentation of a stochastic process, properties of ARMA processes in thefrequency domain; estimation of the spectrum, Kalman filter.
MTH517A	TIME SERIES ANALYSIS	3-1-0-0-11	Linear stationary processes, AR, MA, ARMA and ARIMA; identification, estimation of the models; forecasting time series regression; Fourier analysis, spectral representation of a stochastic process, properties of ARMA processes in the frequency domain; estimation of the spectrum, Kalman filter.
MTH520	NUMERICAL LINEAR ALGEBRA	3-1-0--4	Computer arithmetic. Vector and matrix norms. Condition number of a matrixand its applications. Singular value decomposition of a matrix and its applications. Linear least squares problem. Householder matrices and their applications. Numerical methods for matrix eigenvalue problem. Numerical methods for systems and control.
MTH522	FINITE ELEMENT METHOD	3-1-0-0-4	Introduction and motivation, Weak formulation of BVP and Galerkin approximation, Piecewise polynomial spaces and finite element method, Computer implementationof FEM, Results from Sobolev spaces, Variational formulation of elliptic BVP, LaxMilgram theorem, Estimation for general FE approximation, Constructionof FE spaces, Polynomial approximation theory in Sobolev spaces, Variational problem for second order elliptic operators and approximations, Mixed methods, Iterative techniques.
MTH522A	FINITE ELEMENT METHOD	3-1-0-0-11	Introduction and motivation, Weak formulation of BVP and Galerkin approximation, Piecewise polynomial spaces and finite element method, Computer implementation of FEM, Results from Sobolev spaces, Variational formulation of elliptic BVP, LaxMilgram theorem, Estimation for general FE approximation, Constructionof FE spaces, Polynomial approximation theory in Sobolev spaces, Variational problem for second order elliptic operators and approximations, Mixed methods, Iterative techniques.
MTH523	FLUID MECHANICS	3-1-0-0-4	Review and General Properties of Navier Stokes Equations; Some Exact solutionsof NS equations; Introduction to boundary layer theory; Introduction to turbulent flow; Introduction to compressible flow; Applications.
MTH523A	FLUID MECHANICS	3-1-0-0-11	Review and General Properties of Navier Stokes Equations; Some Exact solutionsof NS equations; Introduction to boundary layer theory; Introduction to turbulent flow;

			Introduction to compressible flow; Applications.
MTH524	ALGORITHMS	3-1-0-0-4	Preliminaries: Introduction to algorithms; Analyzing algorithms: space and timecomplexity; growth of functions; summations; recurrences; sets, etc. GreedyAlgorithms: General characteristics; Graphs: minimum spanning tree; Theknapsack problem; scheduling. Divide and Conquer: Binary search; Sorting: sorting by merging, qucksort. Dynamic Programming: Elements of dynamic programming; The principle of optimality; The knapsack problem; Shortest paths; Chained matrix multiplication. Graph Algorithms: Depthfirst search; Breadth first search; Backtracking; Branch and bound. Polynomials and FFT: Representation of polynomials; The DFT and FFT; Efficient FFT implementation. Number Theoretic Algorithms: Greatest common divisor; Modular arithmetic; Solving modular linear equations. Introduction to cryptography. Computational Geometry: Line segment properties; Intersection of any pair of segments; Finding the convex hull; Finding the closest pair of points. Heuristic and Approximate Algorithms: Heuristic algorithms; Approximate algorithms; NPhard approximation problems.
MTH524A	ALGORITHMS	3-0-0-0-9	Preliminaries: Introduction to algorithms; Analyzing algorithms: space and timecomplexity; growth of functions; summations; recurrences; sets, etc. Greedy Algorithms: General characteristics; Graphs: minimum spanning tree; The knapsack problem; scheduling. Divide and Conquer: Binary search; Sorting: sorting by merging, quicksort. Dynamic Programming: Elements of dynamic programming; The principle of optimality; The knapsack problem; Shortest paths; Chained matrix multiplication. Graph Algorithms: Depth first search; Breadth first search; Backtracking; Branch and bound. Polynomials and FFT: Representation of polynomials; The DFT and FFT; Efficient FFT implementation. Number Theoretic Algorithms: Greatest common divisor; Modular arithmetic; Solving modular linear equations. Introduction to cryptography. Computational Geometry: Line segment properties; Intersection of any pair of segments; Finding the convex hull; Finding the closest pair of points. Heuristic and Approximate Algorithms: Heuristic algorithms; Approximate algorithms; NPhard approximation problems.
MTH598	PROJECT-I	0-0-7-0-4	PROJECT I
MTH599	PROJECT- II	0-0-7-0-4	PROJECT II
MTH599.	PROJECT I , II	0-0-0--0	PROJECT I , II
MTH603	MATHEMATICAL MODELLING	3-0-0--4	Elementary mathematical models; Role of mathematics in problem solving; Concepts of mathematical modelling; System approach; formulation, Analyses ofmodels; Sensitivity analysis, Simulation approach; Pitfalls in modelling, Illustrations.
MTH606	BIOMATHEMATIC S	3-0-0--4	Biofluid dynamics; Blood flow & arterial diseases; Transport in intestines& lungs; Diffusion processes in human systems;

			Mathematical study of nonlinear Volterra equations, Stochastic & deterministic models in population dynamicsand epidemics.
MTH610	APPLIED MATRIX THEORY	3-0-0--4	Review of basic lin.alg. canonical factorization. QForms. Courant Fischer minmax & related theorems. PerronFrobenius theory. Matrixstability. Inequalities, ginverse (A, Am, A+). Direct, iterative, projection and rotations methods forsolving linear systems & eigenvalues problems. Applications.
MTH610A	APPLIED MATRIX THEORY	3-0-0-0-9	Review of basic lin.alg. canonical factorization. QForms. Courant Fischer minmax & related theorems. PerronFrobenius theory. Matrix stability. Inequalities, ginverse (A, Am, A+). Direct, iterative, projection and rotations methods forsolving linear systems & eigenvalues problems. Applications.
MTH611	ALGEBRA II	3-1-0-0-4	Fields: definition and examples. Ring of polynomials over a field. Field extensions. Algebraic and transcendental elements, Algebraic extensions. Splittingfield of a polynomial. Algebraic closure of a field, Uniqueness. Normal, separable, purely inseparable extensions. Primitive elements of a field extension simple extensions. Fundamental theorem of Galois. Solvability by radicals Solutions of cubic and quartic polynomials, Insolvabity of quintic and higher degree polynomials. Geometric constructions. Cyclotomic extensions. Finite fields. Cyclotomic polynomials and its properties. Traces and norms. Modules definition, examples and basic properties. Free modules, submodules and quotient modules, isomorphism theorems. Localization. Direct sum and directproducts. Noetherian and Artinian rings and modules, structure of Artinian rings, Hilbert basis theorem. Jordan Holder theorem. Radicals of modules, Nakayama lemma.
MTH611A	ALGEBRA II	3-0-0-0-9	Fields: definition and examples. Ring of polynomials over a field. Field extensions. Algebraic and transcendental elements, Algebraic extensions. Splitting field of a polynomial. Algebraic closure of a field, Uniqueness. Normal, separable, purely inseparable extensions. Primitive elements of a field extension simple extensions. Fundamental theorem of Galois. Solvability by radicals Solutions of cubic and quartic polynomials, Insolvabity of quintic and higher degree polynomials. Geometric constructions. Cyclotomic extensions. Finite fields. Cyclotomic polynomials and its properties. Traces and norms. Modules definition, examples and basic properties. Free modules, submodules andquotient modules, isomorphism theorems. Localization. Direct sum and direct products. Noetherian and Artinian rings and modules, structure of Artinian rings, Hilbert basis theorem. Jordan Holder theorem. Radicals of modules, Nakayama lemma.
MTH612	INTRODUCTION TO COMMUTATIVE ALGEBRA	3-0-0--4	Commutative rings, ideals, prime and maximal ideals, Noetherian Artinian rings, Primary decomposition and Noetherian rings, Modules over commutative rings, Exact sequences, the Hom and tensorufunctors, rings and

			modules of fractions, integral dependence, valuations and dedekind domains.
MTH612A	INTRODUCTION TO COMMUTATIVE ALGEBRA	3-0-0-0-9	Commutative rings, ideals, prime and maximal ideals, Noetherian Artinian rings, Primary decomposition and Noetherian rings, Modules over commutative rings, Exact sequences, the Hom and tensorufunctors, rings and modules of fractions, integral dependence, valuations and dedekind domains.
MTH620	MEASURE THEORY	3-1-0-0-4	Algebras and salgebras, Measures, Outer measures, Lebesgue measure in Rn, Completeness and regularity. Measurable functions and their properties, Convergence in measure, Integral, Convergence theorems. Signed and complex measures, Radon Nikodym theorem, Lebesgue decompostion theorem, Lpspaces and their dual. Product measures, Construction, Fubini theorem and itsapplications, Differentiation of measures.
MTH620A	MEASURE THEORY	3-0-0-0-9	Algebras and salgebras, Measures, Outer measures, Lebesgue measure in Rn, Completeness and regularity. Measurable functions and their properties, Convergence in measure, Integral, Convergence theorems. Signed and complex measures, Radon Nikodym theorem, Lebesgue decompostion theorem, Lpspaces and their dual. Product measures, Construction, Fubini theorem and its applications, Differentiation of measures.
MTH621	FOURIER ANALYSIS	3-0-0--4	Fourier series; Norm and pointwise convergence, Approximate identities, Plancherel theorem, Conjugation, Maximal functions, Classical Hardy spaces, F. and M. Riesz theorem, Interpolation of linear operators. Fourier & Fourier Stieltjes transforms, Tempered distributions, PaleyWiener theorems. WienerTauberian theorems & applications.
MTH621A	FOURIER ANALYSIS	3-0-0-0-9	Fourier series; Norm and pointwise convergence, Approximate identities, Plancherel theorem, Conjugation, Maximal functions, Classical Hardy spaces, F. and M. Riesz theorem, Interpolation of linear operators. Fourier & Fourier Stieltjes transforms, Tempered distributions, PaleyWiener theorems. Wienern Tauberian theorems & applications.
MTH624	DIFFERENTIABLE MANIFOLDS AND LIE GROUPS	3-0-0--4	Differentiable manifolds; Tangent space. Vector fields; Frobenius theorem; Relation between Lie subalgebras & Lie subgroups; Cartans theorem on closed subgroups; One parameter subgroups, Exponential maps; Adjoint representation; Homogeneous spaces; Compact Lie groups; Symmetric spaces.
MTH624A	DIFFERENTIABLE MANIFOLDS AND LIE GROUPS	3-0-0-0-9	Differentiable manifolds; Tangent space. Vector fields; Frobenius theorem; Relation between Lie subalgebras & Lie subgroups; Cartans theorem on closedsubgroups; One parameter subgroups, Exponential maps; Adjoint representation; Homogeneous spaces; Compact Lie groups; Symmetric spaces.
MTH627	APPLIED HARMONIC ANALYSIS	3-0-0-0-4	Basic Fourier Analysisa review Convolutions, Multipliers and Filters, PoissonSummation Formula, Shannon Sampling Discrete Fourier Transform, Fast FourierTransform, Discrete Wavelets, Continuous Wavelets,

			Uncertainty Principles, Radar Ambiguity, Phase Retrieval, Random Transform, Basic Properties, Convolutionand Inversion, Computerized Tomography
MTH628	TOPICS IN TOPOLOGY	3-0-0--4	Classification of 2-dimensional surfaces; Fundamental group; Knots and covering spaces; Braids and links; Simplicial homology groups and applications; Degree and Lefschetz Number; BorsukUlam Theorem; Lefschetz FixedPoint Theorem.
MTH628A	TOPICS IN TOPOLOGY	3-0-0-0-9	Classification of 2dimensional surfaces; Fundamental group; Knots and covering spaces; Braids and links; Simplicial homology groups and applications; Degree and Lefschetz Number; BorsukUlam Theorem; Lefschetz Fixed Point Theorem.
MTH631	APPROXIMATION THEORY	3-0-0--4	Best approximation in normed spaces. Tchebycheff systems. Tchebycheff Weierstrass Jackson Bernstein Zygmund Nikolaev etc. theorems. Fourier series, Splines, Convolutions, Linear positive, Variation diminishing, Simultaneous etc. approximations. Direct inverse saturation theorems. Applications.
MTH631A	APPROXIMATION THEORY	3-0-0-0-9	Best approximation in normed spaces. Tchebycheff systems. Tchebycheff Weierstrass Jackson Bernstein Zygmund Nikolaev etc. theorems. Fourierseries, Splines, Convolutions, Linear positive, Variation diminishing, Simultaneousetc. approximations. Direct inverse saturation theorems. Applications.
MTH632	SPECTRAL THEORY FOR SELF-ADJOINT OPERATORS	3-0-0-0-4	Unbounded Operators, Matrix representation, Selfadjointness Criterion, Quadratic Forms, Differential Operators, Selfadjoint Extensions, Functional Calculus, Spectra of Selfadjoint Operators, Semianalytic vectors, Theorems of Nelson and Nussbaum, States and Observables, Superselection Rules, Position and Momentum, An Uncertainty Principle of Bargmann, Canonical Commutation Relations, Schrodinger representations, Schrodinger Operators, Selfadjointness, A Theorem of Kato, Spectral Theory for Schrodinger Operators, Discrete Spectrum, Essential Spectrum **Course Reference**: 1. N. Akhiezer, I. Glazman, Theory of Linear Operators in Hilbert Space II, Dover, 1961; 2. J. Blank, P. Exner, M. Havlivcek, Hilbert Space Operators in Quantum Physics, Springer, 2008; 3. T. Kato, Perturbation Theory, Springer, 1976; 4. M. Miklavcic, Applied Functional Analysis and Partial Differential Equations, World Scientific, 1998; 5. M. Reed and B. Simon, Methods of Modern Mathematical Physics II, Academic Press, 1975.
MTH632A	SPECTRAL THEORY FOR SELF-ADJOINT OPERATORS	3-0-0-0-9	Unbounded Operators, Matrix representation, Self adjointness Criterion, Quadratic Forms, Differential Operators, Selfadjoint Extensions, Functional Calculus, Spectra of Selfadjoint Operators, Semianalytic vectors, Theorems of Nelson and Nussbaum, States and Observables, Superselection Rules, Position and Momentum, An Uncertainty Principle of Bargmann, Canonical Commutation Relations, Schrodinger representations, Schrodinger Operators, Self adjointness, A

			Theorem of Kato, Spectral Theory for Schrodinger Operators, Discrete Spectrum, Essential Spectrum N. **Course Reference**: 1.N. Akhiezer, I. Glazman, Theory of Linear Operators in Hilbert Space II, Dover, 1961; 2. J. Blank, P. Exner, M. Havlivcek, Hilbert Space Operators in Quantum Physics, Springer, 2008; 3. T. Kato, Perturbation Theory, Springer, 1976; 4. M. Miklavcic, Applied Functional Analysis and Partial Differential Equations, World Scientific, 1998; 5. M. Reed and B. Simon, Methods of Modern Mathematical Physics II, Academic Press, 1975.
MTH633	INTRODUCTION TO HYPERBOLIC GEOMETRY	3-0-0-0-4	Models of Hyperbolic Space: Upper Half Space Model & Disc Model; Isometries of Hyperbolic Space; Geodesics; Slimness of Triangles and Exponential Divergence of Geodesics in Hyperbolic Space; Isoperimetric Inequalities in Euclidean & Hyperbolic Space; Boundary of Hyperbolic Space; Review of Covering Spaces, Local Isometries and Fundamental groups; Properly Discontinuous Group actions; Fundamental Domains; Hyperbolic Surfaces. * Lectures on Hyperbolic Geometry; **Course Reference**: 1. Riccardo Benedetti and Carlo Petronio; Springer Verlag* Kleinian Groups; Bernard Maskit; SpringerVerlag; 2. Metric Spaces of NonPositive Curvature; Martin R. Bridson, Andre Haefliger; Springer; 3. Fuchsian Groups; Svetlana Katok; The University of Chicago Press; 4. A course on geometric group theory; Brian H. Bowditch, preprint.
MTH633A	INTRODUCTION TO HYPERBOLIC GEOMETRY	3-0-0-0-9	Models of Hyperbolic Space: Upper Half Space Model & Disc Model; Isometries of Hyperbolic Space; Geodesics; Slimness of Triangles and Exponential Divergence of Geodesics in Hyperbolic Space; Isoperimetric Inequalities in Euclidean & Hyperbolic Space; Boundary of Hyperbolic Space; Review of Covering Spaces, Local Isometries and Fundamental groups; Properly Discontinuous Group actions; Fundamental Domains; Hyperbolic Surfaces. * Lectures on Hyperbolic Geometry; **Course Reference**:1. Riccardo Benedetti and Carlo Petronio; Springer Verlag; 2. Kleinian Groups; Bernard Maskit; SpringerVerlag; 3. Metric Spaces of NonPositive Curvature; Martin R. Bridson, Andre Haefliger; Springer; 4. Fuchsian Groups; Svetlana Katok; The University of Chicago Press; 5. A course on geometric group theory; Brian H. Bowditch, preprint.
MTH634	BASES IN LOCALLY CONVEX SPACES AND KOETHE SEQUENCE SPACES	3-0-0--4	Preliminaries, Elements of basis theory, Types of bases, Summability (summationof infinite series), Koethe sequence spaces, Bases in OTVS, Isomorphism theorems.
MTH637	TOPICS IN OPERATOR THEORY AND HARMONIC ANALYSIS	3-0-0--4	Operators on Hilbert spaces: Compact operators, Schatten class and Hilbert Schmidt operators, Spectral theorem. Fourier series, Smooth functions anddistributions. Hardy spaces, Carleson measures, H1BMO duality. Hankel and Toeplitz operators on H2. Representation theory of compact

			groups, Representationof SU (2) and SO (3).
MTH637A	TOPICS IN OPERATOR THEORY AND HARMONIC ANALYSIS	3-0-0-0-9	Operators on Hilbert spaces: Compact operators, Schatten class and Hilbert Schmidt operators, Spectral theore. Fourier series, Smooth functions and distributions. Hardy spaces, Carleson measures, H1BMO duality. Hankel and Toeplitz operators on H2. Representation theory of compact groups, Representation of SU (2) and SO (3).
MTH638	ABSTRACT HARMONIC ANALYSIS	3-0-0-0-4	Banach Algebras and Spectral theory, Locally compact groups, Basic representation theory, Analysis on Locally compact abelian group, Analysis on compact groups, Group C* algebra and structure of dual space. **Course Reference**: 1. G.B. Folland: Course in Abstract harmonic analysis, Studies in Advanced Maths., CRC Press, Boca Raton, etc., 1995.
MTH638A	ABSTRACT HARMONIC ANALYSIS	3-0-0-0-9	Banach Algebras and Spectral theory, Locally compact groups, Basic representation theory, Analysis on Locally compact abelian group, Analysis on compact groups, Group C* algebra and structure of dual space. **Course Reference**: 1. G.B. Folland: Course in Abstract harmonic analysis, Studies in Advanced Maths., CRC Press, Boca Raton, etc., 1995.
MTH639	LOCALLY CONVEX SPACES	3-0-0--4	Topological linear spaces, Equicontinuity, Function spaces, Convexity & convex topological spaces, HahnBanach theorem, Barrelled spaces, Principle of uniform boundedness, Bornological spaces, Duality theory (Arens Th., Mackey topology, Stopology, Polarity).
MTH639A	LOCALLY CONVEX SPACES	3-0-0-0-9	Topological linear spaces, Equi continuity, Function spaces, Convexity & convex topological spaces, Hahn Banach theorem, Barrelled spaces, Principle of uniform boundedness, Bornological spaces, Duality theory (Arens Th., Mackey topology, Stopology, Polarity).
MTH640	SEVERAL COMPLEX VARIABLES	3-0-0--4	Cauchy integral formula, Taylor series, Associated radii of convergence, Analytic functions, Reinhardt domain, Logarithmic convexity, Laurents expansion, Envelope of holomorphy, Goldbergs growth parameter, Factorization, Weirestrass preparation theorem, Types of singularity, Domain of holomorphy, Complex analytic structure.
MTH641	INTRODUCTION TO LIE ALGEBRAS AND REPRESENTATIO N THEORY	3-0-0-0-4	Definitions and first examples. Classical Lie algebras. Ideals and homomorphisms. Niporent Lie algegras. Engel's theorem. Solvable Lie algebras. Lie's theorem. Jordan Chevalley Decomposition. Radical and semisimplicity. The Killing form and Cartan's criterion. THe structure of semisimple Lie algebras. Complete reducibility and Weyls theorem. Representation theory of the Lie algebra sl(2). Total sub algebras and root systems. Integrality properties. Simple Lie algebras and irreducible root systems. 1. Humphreys, James E. (1972), Introduction to Lie Algebras and Representation Theory, Berlin, New York.2. J.P. Serre, Complex semisimple Lie algebras (trnslated from French: Algebras de Lie complex semisimple). 24.09.14.
MTH641A	INTRODUCTION TO LIE	3-0-0-0-9	Definitions and first examples. Classical Lie algebras. Ideals and homomorphisms. Niporent Lie algegras. Engel's

	ALGEBRAS AND REPRESENTATION THEORY		theorem. Solvable Lie algebras. Lie's theorem. Jordan Chevalley Decomposition. Radical and semisimplicity. The Killing form and Cartan's criterion. THe structure of semisimple Lie algebras. Complete reducibility and Weyls theorem. Representation theory of the Lie algebra sl (2). Total subalgebras and root systems. Integrality properties. Simple Lie algebras and irreducible root systems. **Course Reference:** 1. Humphreys, James E. (1972), Introduction to Lie Algebras and Representation Theory, Berlin, New York; 2. J.P. Serre, Complex semisimple Lie algebras (trnslated from French: Algebras de Lie complex semisimple). 24.09.14
MTH644	COMPLEX FUNCTION THEORY	3-0-0--4	Fundamental theorems, Winding number & applications, Normal families, Riemann mapping theorem, Fundamentals of univalent functions & entire functions, Phragmen Lindelf theorems, Gamma, Riemannzeta functions; Harmonic functions, Dirichlet problem for disc, Analytical continuation, Runges theorem.
MTH647	COMPLEX ANALYTIC DYNAMICS AND FRACTALS	3-0-0--4	Chordal & spherical metrics, Normal families. Iteration of polynomials andrational functions, Periodic points & orbits, Julia & Fatous sets and their characterizations, Dynamics of Julia and Fatous sets for quadratic, Rational & entire functions; The Mandelbrot set. Julia sets & fractals, Self similarity and fractal dimension.
MTH647A	COMPLEX ANALYTIC DYNAMICS AND FRACTALS	3-0-0-0-9	Chordal & spherical metrics, Normal families. Iteration of polynomials andrational functions, Periodic points & orbits, Julia & Fatous sets and their characterizations, Dynamics of Julia and Fatous sets for quadratic, Rational & entire functions; The Mandelbrot set. Julia sets & fractals, Self similarity and fractal dimension.
MTH648	DIFFERENTIAL GEOMETRY	3-1-0-0-4	Theory of Space CurvesThe Serret Frenet formulas. Gauss Theory of Surfaces First and second fundamental form, Examples, Weingarten map, Principal curvatures, Gaussian curvature, Examples. Computation of the curvature in standard spaces: Sphere, Torus, Surfaces of revolution etc. LeviCivita connection Uniqueness, Gauss theorem Egregium, Hilberts theorem on the positivity of curvature at a point on a compact surface in R3. Geodesics, Equations of geodesics, Examples. Jacobi fields, Conjugate points etc. Riemannian area element on a surface, Gauss Bonnet theorem. Differentiable manifold, Differentiable structure. Submanifolds, Immersions, Embeddings. Metric tensor, Riemannian connection and curvature.
MTH648A	DIFFERENTIAL GEOMETRY	3-0-0-0-9	Theory of Space CurvesThe Serret Frenet formulas. Gauss Theory of Surfaces First and second fundamental form, Examples, Weingarten map, Principal curvatures, Gaussian curvature, Examples. Computation of the curvature instandard spaces: Sphere, Torus, Surfaces of revolution etc. Levi Civita connection Uniqueness, Gauss theorem Egregium, Hilberts theorem on the positivity of curvature at a point on a compact surface in R3. Geodesics, Equations of geodesics, Examples. Jacobi fields, Conjugate points etc. Riemannian area element on a surface, Gauss Bonnet

			theorem. Differentiable manifold, Differentiable structure. Submanifolds, Immersions, Embeddings. Metric tensor, Riemannian connection and curvature.
MTH649	ALGEBRAIC TOPOLOGY	3-1-0-0-4	Homotopy, Path homotopy. The fundamental group. Covering spaces. The fundamental group of the circle, S1, sphere, S2, Surfaces 2-dimensional, Punctured plane etc. Techniques of calculation. The special Van Kampen theorem. Essential and Inessential maps Applications. The fundamental theorem of algebra, Browers fixed point theorem for the disc etc. Triangulations. Simplical complexes. Barycentric subdivision. Simplical mappings, The simplical approximation theorem. Simplical homology groups; Calculations for cone complex, Sn etc. The Euler Poincare formula. The Lefschetz fixed point theorem. Singular homology groups, Topological invariance, The exact homology sequence. The Eilenberg Steenrod axioms.
MTH649A	ALGEBRAIC TOPOLOGY	3-0-0-0-9	Homotopy, Path homotopy. The fundamental group. Covering spaces. Thefundamental group of the circle, S1, sphere, S2, Surfaces 2-dimensional, Punctured plane etc. Techniques of calculation. The special Van Kampen theorem. Essential and Inessential maps Applications. The fundamental theorem of algebra, Browers fixed point theorem for the disc etc. Triangulations. Simplical complexes. Barycentric subdivision. Simplical mappings, The simplical approximation theorem. Simplical homology groups; Calculations for cone complex, Sn etc. The Euler Poincare formula. The Lefschetz fixed point theorem. Singular homology groups, Topological invariance, The exact homology sequence. The Eilenberg Steenrod axioms.
MTH652A	ADVANCED CALCULUS	3-0-0-0-9	Least upper bound principle; limits; monotone sequence; subsequences, Bolzano Weierstrass, Cauchy sequence, copleteness; countable and uncountable sets; convergence of series, conditional convergence; equivalence of completeness of R; limsup, liminf, convergent series; absolute and conditional convergent, Riemann Rearragngement Theorem; convergence in R, open sets and closed sets on R; Cantor intersection Theorem, Cantor set; limits and continuity; discontinuous functions; properties of continuous functions; uniform continuity; monotone functions; differentiation, Mean Value Theorem; Riemann integration; Fundamental Theorem of Calculus; sequence and series of functions; point wise convergence; uniform convergence, Weierstrass Mtest, Dedekind test; uniform convergence and continuity; term by term integration and differenciation; power series; Taylor series, Weierstrass Approximation Theorem; analytic functions; Fourier series; differenciation of f:R>R; partial derivatives; chain rule; higher derivatives, local extrema; Taylor expansion; multiple integrals, determinant and volume, Jacobians. **Course Reference**: 1. K R Davidson and A P Donsig: Real Analysis and Applications, Springer, 2010; 2. R S Strichartz: The Way of Analysis, Jones and Bartlet Mathematics, 2010. 27-MAR-2014

MTH653	INTEGRAL EQUATIONS	3-0-0--4	Volterra and Fredholm integral equations, Resolvent Kernels. Operator equations, Fredholm theory, Hilbert Schmidt theory. Nonlinear integral equations, Singular integral equations.
MTH653A	INTEGRAL EQUATIONS	3-0-0-0-9	Volterra and Fredholm integral equations, Resolvent Kernels. Operator equations, Fredholm theory, Hilbert Schmidt theory. Nonlinear integral equations, Singular integral equations.
MTH656	SOBOLEV SPACES AND APPLICATIONS	3-0-0--4	Elements of operator theory and Hilbert spaces; Introduction to the theoryof distributions. Sobolev Spaces: Imbedding and compactness theorems, Fractional spaces and elements of trace theory. Applications to elliptic equations or parabolic equations.
MTH656A	SOBOLEV SPACES AND APPLICATIONS	3-0-0-0-9	Elements of operator theory and Hilbert spaces; Introduction to the theory of distributions. Sobolev Spaces: Imbedding and compactness theorems, Fractional spaces and elements of trace theory. Applications to elliptic equations or parabolic equations.
MTH657	GRAPH THEORY	3-1-0-0-4	Basic definitions. Blocks. Ramsey Numbers. Degree sequences. Connectivity.Eulerian and Hamiltonian Graphs. Planar graphs and 5 colour theorem. Chromatic numbers. Enumeration. MaxFlow MinCut Theorem. Groups and graphs. Matrices and graphs. Matchings and Halls Marriage Theorem. Eigen values of graphs.
MTH657A	GRAPH THEORY	3-0-0-0-9	Basic definitions. Blocks. Ramsey Numbers. Degree sequences. Connectivity.Eulerian and Hamiltonian Graphs. Planar graphs and 5colour theorem. Chromatic numbers. Enumeration. Max Flow Min Cut Theorem. Groups and graphs. Matrices and graphs. Matchings and Halls Marriage Theorem. Eigen values of graphs.
MTH658	NONLINEAR DYNAMICAL SYSTEMS	3-0-0--4	Picard's theorem, Boundedness of solutions, Omega limit points of bounded trajectories. LaSalle's invariance principle; Stability via Lyapanov's indirect method,Converse Lyapanov functions, Sublevel sets of Lyapanov functions, Stability viaLyapanov's direct method, Converse Lyapanov's theorems, Brokett's theorem,Applications to control system; Stable and unstable manifolds of equilibria, Stablemanifold theorem, HartmanGrobman theorem, Examples and applications,Center manifold theorem, Center manifold theorem, Normal form theory,Examples and applications to nonlinear systems and control; Poincare map, andstability theorems for periodic orbits; Elementary Bifurcation theory.
MTH658A	NONLINEAR DYNAMICAL SYSTEMS	3-0-0-0-9	Picard's theorem, Boundedness of solutions, Omega limit points of bounded trajectories. LaSalle's invariance principle; Stability via Lyapanov's indirect method,Converse Lyapanov functions, Sublevel sets of Lyapanov functions, Stability viaLyapanov's direct method, Converse Lyapanov's theorems, Brokett's theorem, Applications to control system; Stable and unstable manifolds of equilibria, Stable manifold theorem, Hartman Grobman theorem, Examples and applications,Center manifold theorem, Center manifold theorem, Normal form theory,Examples and applications to

			nonlinear systems and control; Poincare map, and stability theorems for periodic orbits; Elementary Bifurcation theory.
MTH659A	NONLINEAR ANALYSIS AND ITS APPLLICATIONS TO PDE	3-0-0-0-9	Review of topic in functional analysis and Soblev space mapping between Banach spaces degree theory, Bifurcation theory. Variation Method: Constrained critical points, Deformation and Palais condition, Linking Theorems, Mountain Pass theorem and Ekeland Variation principal
MTH664	TRIBOLOGY	3-0-0--4	The fundamentals of lubrication, friction & wear. Boundary lubrication, Hydrodynamic lubrication, Elasto hydrodynamic lubrication. Compressibility and thermal effects, Non-Newtonian lubrication, Roughness effects, Magneto hydrodynamic effects, Application to engineering & human systems.
MTH664A	TRIBOLOGY	3-0-0-0-9	The fundamentals of lubrication, friction & wear. Boundary lubrication, Hydrodynamic lubrication, Elasto hydrodynamic lubrication. Compressibility and thermal effects, Non-Newtonian lubrication, Roughness effects, Magneto hydrodynamic effects, Application to engineering and human systems.
MTH665A	ASYMPTOTIC STATISTICS		Introduction Approximate Statistical Procedures; Asymptotic Optimality Theory Review of Stochastic Convergence Basic Theory, Stochastic and 0 Symbols, Characteristic Functions; AlmostSure Representations, Convergence of Moments, Convergence Determining Classes; Law of the Iterated Logarithm, Lindeberg Feller Theorem, Convergence in Total Variation Delta Method Basic Result, Variance Stabilizing Transformations; Higher Order Expansions, Uniform Delta Method; Moments M and Z Estimators Introduction; Consistency; Asymptotic Normality; Estimated Parameters, Maximum Likelihood Estimators, Classical Conditions, OneStep Estimators; Rates of Convergence; Argmax Theorem W. Contiguity Likelihood Ratios; Contiguity. Local Asymptotic Normality Introduction, Expanding the Likelihood Convergence to a Normal Experiment, Maximum Likelihood; Limit Distributions under Alternatives; Local Asymptotic Normality. Stochastic Convergence in Metric Spaces Metric and Normed Spaces; Basic Properties; Bounded Stochastic Processes. Empirical Processes Empirical Distribution Functions; Empirical Distributions; Goodness of Fit Statistics; Random Functions; Changing Classes; Maximal Inequalities Functional Delta Method von Mises Calculus; Hadamard Differentiable Functions; Some Examples Bootstrap Introduction, Consistency; Higher Order Correctness W.
MTH666A	CATEGORY THEORY		1. Structure vs. property: monoids, groups, preorders, partial orders; structure preserving maps: homomorphisms, continuous maps; category; homsets and duality; functor covariant and contravariant; natural transformations. (3 lectures); 2. Small, locally small and large categories; set theory vs category theory; Russell's paradox and the category of all categories; skeletons and axiom of choice. (1 lecture); 3. Isomorphism; groupoid; monomorphism and

			epimorphism; full, faithful, essentially surjective functors, equivalence of categories; building even morecategories from the old ones: slice categories and local property, categories, functor categories, congruence and quotients. (3 lectures); 4. Representable functors; Yoneda lemma and Yoneda embedding; separating anddetecting families; injective and projective objects; representables are projective. (3 lectures); 5. Adjunctions: definition and examples; initial and terminal objects; relation to comma categories; composition of adjoint functors; units, counits and characterization of adjoint functors; equivalence gives adjoint functors. (4lectures); 6. Categorical properties: initial and terminal objects, products, coproducts; diagrams and (co)cones; (co)limits of a given shape; (co)equalizers, regularmono(epi) morphisms; pullbacks and pushouts; direct and inverse limits. (2lectures); 7. Constructing all (co)limits from some of them; (co)complete categories; absolute (co)limits; preservation, creation and reflection of (co)limits; right adjoints preserve limits. (2 lectures).
MTH671A	INTRODUCTION TO ARITHMETIC GEOMETRY		padic numbers: nonarchimedean absolute values, valuations, Ostrowski theorem, Cauchy sequences, padic integers, completions, Hensels lemma, structure of Z and Q. Quadratic forms: definition of quadratic forms and bilinear forms, equivalence of quadratic forms, local global principle (HasseMinkowski theorem), rational points on conics. [8 lectures]Infinite Galois Theory : Profinite groups and profinite topology, Infinite Ga lois extensions and Galois group as profinite groups, absolute Galois groups, the fundamental theorem of Galois theory (for infinite extensions), absolute Galois group of finite fields, Frobenius automorphism, absolute Galois group of Q and Qp.Geometry of curves over Q: Affine Varieties and projective varieties, curvesand function fields, divisors on curves, the RiemannRoch theorem (state ment without proof), Elliptic curves over Q, Group law on elliptic curves, Weierstrass equations, action of the absolute Galois group of Q over Q points of elliptic curves, Weak MordellWeil Theorem, MordellWeil Theorem, Faltings Theorem
MTH678A	TECHNIQUES IN COMBINATORICS		Techniques in Combinatorics Pre-requisites: students are expected to have a very good background in Analysis-I (MTH301A), Algebra-I (MTH201A), Linear Algebra (MTH204A), Probability and Statistics as well as in Set theory and Logic (MTH302A) or Set theory and Discrete Mathematics (MTH202A). Some knowledge of the basics of graph theory and Fourier analysis is desirable but not mandatory. Aims of the course: Combinatorics is an area of mathematics that, at elementary level, deals with problems in counting/enumeration, especially in the realm of finite sets. However, the supply of problems as well as the methods to solve them come from a variety of domains of mathematics ranging from algebra, analysis, number theory, geometry, probability theory, and so on. Leon Mirsky has rightly said; combinatorics is a range of linked studies which have something in common and yet diverge widely in their

			objectives, their methods, and the degree of coherence they have attained. This, course will introduce techniques from three popular branches of combinatorics that are of areas of active research currently, namely extremal combinatorics, extremal graph theory and additive combinatorics over dyadic groups. The emphasis will be on the techniques than the solutions of the problems. Extremal combinatorics with set systems: Hall's marriage theorem, Sperner's lemma, Lubell-Yamamato-Meshalkin inequality, Kruskal-Katona theorem, Erdos Ko-Rado theorems [4 weeks]; 2. Extremal graph theory: Mantel & rsquo's theorem, Turan's theorem, Dirac's theorem, Erdos-Stone-Simonovits theorem, Szemeredi & rsquo's regularity lemma, Triangle,removal lemma, Roth's theorem for 3 term arithmetic progressions [4 weeks]; 3. Additive combinatorics with dyadic groups: Discrete Fourier transform, Plancherel & rsquo's theorem, Bogolyubov's lemma, Arithmetic regularity and removal lemmas, Coincidence of algebraic and statistical independence of Bernoulli r. v s, Rudin's inequality, Sets with small sumsets: Rusza's covering lemma, Freiman's theorem [5 weeks] **Course Reference**: 1. Bollob. Combinatorics: set systems, hypergraphs, families of vectors, and combinatorial probability. Cambridge, University Press, 1986; 2. Extremal graph theory. Courier Corporation, 2004; 3. Tao, Terence, and Van H. Vu. Additive combinatorics Vol. 105. Cambridge University Press, 2006; Dated: 31/08/2017 Proposer: Amit Kuber
MTH681	STATISTICAL DECISION THEORY	3-0-0--4	Decision function, Risk function, Optimal decision rules, Admissibility & completeness, The minimax theorem, The complete class theorem, Sufficient statistics. Invariant decision problems, Admissible & minimax invariant rules, The Pitman estimates, Estimation of a distribution function.
MTH682	ORDER STATISTICS	3-0-0--4	Basic distribution theory, Moments of order statistics including recurrence relations, Bounds and approximations, Estimation of parameters, Life testing, Short cut procedures, Treatment of outliers, Asymptotic theory of extremes.
MTH682A	ORDER STATISTICS	3-0-0-0-9	Basic distribution theory, Moments of order statistics including recurrence relations, Bounds and approximations, Estimation of parameters, Life testing, Short cut procedures, Treatment of outliers, Asymptotic theory of exremes.
MTH683	NON-PARAMETRIC INFERENCE	3-0-0--4	Order statistics, Tests of goodness of fit, Sign & signed rank tests, WaldWolfowitz, Kolmogorov Smirnov, Median & MannWhitney tests, Linear ranktests for the location problem & scale problem, Measures of association, Asymptotic relative efficiency.
MTH684	STATISTICAL SIMULATION, DATA ANALYSIS AND MODEL BUILDING	3-0-0--4	Introduction to simulation & MonteCarlo studies; Generation of random variables. Interactive computational & graphical techniques in model building; Data basedinference methods such as JackKnife, Bootstrap and cross validation techniques; Use of statistical packages in data analysis.
MTH685	TIME SERIES ANALYSIS:	3-0-0--4	Linear stationary processes, Auto covariance & spectral density functions & moving average processes, Linear

	FORECASTING AND CONTROL		nonstationary processes, Model estimation & identification, Forecasting, Transfer function models, Design for discrete control.
MTH686	NON-LINEAR REGRESSION	3-0-0--4	Estimation methods, Commonly encountered problems in estimation, Statistical inference, Multiresponse nonlinear model, Asymptotic theory, Computational methods.
MTH686A	NON-LINEAR REGRESSION	3-0-0-0-9	Estimation methods, Commonly encountered problems in estimation, Statistical inference, Multiresponse nonlinear model, Asymptotic theory, Computational methods.
MTH690A	PROBABILISTIC THEORY OF PATTERN RECOGNITION	3-0-0-0-9	Results of convergence in almost sure sense and in probability, DCT, Basic inequalities, Conditional expectation, Methods of resampling. Introduction to discriminant analysis, Basyes; risk, and its properties. Distance measures for deensity functions, and its relation with Bayes; risk. Empirical Bayes; risk and its convergence. Parametric methods: Maximum likelihood principle Fisher's Linear Discriminant Function (LDA), Quadratic Discriminat Analysis (QDA). Consistency results. Logistic regression, Linear support vector machines (SVM), Maximum linear separation and Projection pursuit. Non-parametric methods: Kernel discriminant analysis (KDA), nearest neighbor classification (kNN), Universal consistencyh results. Idea of curse of dimensionality, and the use of dimension reduction techniques like random projections pricipal component analysis, etc. Semiparametric methods: Mixture Discriminant Analysis (MDA), Nonlinear SVM, Hybrid classifiesrs, Classification using data depth, Related consistency results. **Course Reference**: 1. Pattern Calssification by Richard Duda, Peter Hart and David Sstork, Wiley; 2. A Probabilistic Theory of Pattern Recognition by Luc Devroye, Laszlo Gyorfi and Gabor Lugosi. Springer; 3. The Elements of Statistical Learning: Data Mining, Inference, and Prediction by Trevor Hastie, Robert Tibshirani, Jerome Friedman. Springer. 05-apr-2016
MTH691	NUMERICAL LINEAR ALGEBRA	3-0-0--4	Triangular form, Matrix norms, Conditioning of linear systems, Direct methods (Gauss, Cholesky, Householder), Iterative methods (Jacobi, GaussSeidel, Relaxation) for solving linear systems, Computing of eigenvalues & eigenvectors (Jacobi, Givens Householder, QR, Inverse methods), Conjugate gradient method & its preconditioning.
MTH691A	NUMERICAL LINEAR ALGEBRA	3-0-0-0-9	Triangular form, Matrix norms, Conditioning of linear systems, Direct methods (Gauss, Cholesky, Householder), Iterative methods (Jacobi, Gauss Seidel, Relaxation) for solving linear systems, Computing of eigenvalues & eigenvectors (Jacobi, Givens Householder, QR, Inverse methods), Conjugate gradient method & its preconditioning.
MTH692	NUMERICAL SOLUTION OF ORDINARY DIFFERENTIAL EQUATIONS	3-1-0-0-4	Introduction. RungeKutta methods derivation, error bounds and error estimates. Weak stability theory for RungeKutta methods. Order and convergence of the general explicit onestep methods. Linear multistep methods derivation, order consistency, zeros tability and convergence. Weak stability theory for genera llinear multistep methods.

			Predictor Corrector methods. Stiff systems.
MTH692A	NUMERICAL SOLUTION OF ORDINARY DIFFERENTIAL EQUATIONS	3-1-0-0-9	Introduction. RungeKutta methods derivation, error bounds and error estimates. Weak stability theory for RungeKutta methods. Order and convergence of the general explicit onestep methods. Linear multistep methods derivation, order consistency, zerostability and convergence. Weak stability theory for general linear multistep methods. Predictor Corrector methods. Stiff systems. 22-MAR-2014
MTH693	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3-1-0-0-4	Basic linear algebra vector and matrix norms and related theorems. Parabolic equations in one and two space dimensions explicit and implicit formulae. Consistency, stability and convergence. Iterative methods for linear systems. Split operator methods. Multilevel difference schemes. Nonlinear equations. Elliptic Equations Dirichlet, Neumann and mixed problems. Direct factorization methods and successive over relaxation (S.O.R.). ADI and conjugate gradient methods. Hyperbolic equations. First order hyperbolic systems in one and twospace dimensions stability and convergence. Second order equations in one andtwo space dimensions. The Galerkin method and applications.
MTH693A	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3-0-0-0-9	Basic linear algebra vector and matrix norms and related theorems. Parabolic equations in one and two space dimensions explicit and implicit formulae. Consistency, stability and convergence. Iterative methods for linear systems. Split operator methods. Multilevel difference schemes. Nonlinear equations. Elliptic Equations Dirichlet, Neumann and mixed problems. Direct factorization methods and successive over relaxation (S.O.R.). ADI and conjugate gradient methods. Hyperbolic equations. First order hyperbolic systems in one and twospace dimensions stability and convergence. Second order equations in one and two space dimensions. The Galerkin method and applications.
MTH694	COMPUTATIONAL FLUID DYNAMICS	3-0-0--4	Conservation laws, Weak solutions & shocks, Monotone difference schemes, Total variation diminishing schemes, Godunov type schemes, Essentially nonoscillatory methods, Flux limiters.
MTH696	SPECTRAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS	3-0-0--4	Galerkin, Collocation & Tau methods, Spectral approximation, The Fourier system, Continuous & discrete Fourier expansion, Orthogonal polynomials in (1,1), Fundamentals of spectral methods for PDEs, Temporal discretization, The Galerkin Collocation method, Implicit spectral equations, Case of nonsmooth solutions.
MTH698	PARALLEL NUMERICAL ALGORITHM	3-0-0--4	Fundamentals of parallel computing; Parallel techniques and algorithms; Parallel algorithms for linear algebriac equations; Design of parallel algorithms for eigenvalue problem; Parallel issues of factorization: singular value decomposition and related problems; Parallel implementation of classical iterative methods; Conjugate gradient method; Parallel methods for ordinary and partial differential equations.

MTH698A	PROJECT II	3-0-0-0-9	Fundamentals of parallel computing; Parallel techniques and algorithms; Parallel algorithms for linear algebriac equations; Design of parallel algorithms for eigenvalue problem; Parallel issues of factorization: singular value decomposition and related problems; Parallel implementation of classical iterative methods; Conjugate gradient method; Parallel methods for ordinary and partial differential equations.
MTH701	MODAL LOGIC	3-0-0--4	Modal Propositional Logic Systems K, T, D, S4, S5, B; Automated Proof Methods, Decidability; Consistency, Frames, Canonical Models, Completeness; FiniteModels, Incompleteness. Algebraic semantics Lindenbaum Tarski Algebras, JonssonTarski Theorem, Goldblatt Thomason Theorem.Modal Predicate Logic Completedness; Automated Proof Methods; Identity. someModal Systems and applications Temporal, dynamic and epistemic Logics, Topology via Modal Logic
MTH701A	MODAL LOGIC	3-0-0-0-9	Modal Propositional Logic Systems K, T, D, S4, S5, B; Automated Proof Methods, Decidability; Consistency, Frames, Canonical Models, Completeness; Finite Models, Incompleteness. Algebraic semantics Lindenbaum Tarski Algebras, JonssonTarski Theorem, Goldblatt Thomason Theorem.Modal Predicate LogicCompletedness; Automated Proof Methods; Identity. Some Modal Systems and applications Temporal, dynamic and epistemic Logics, Topology via Modal Logic
MTH712A	A FIRST COURSE IN ALGEBRAIC NUMBER THEORY	3-0-0-0-9	A brief review of commutative algebra Localization, Noetherian rings and modules, integral extensions, Dedekind domains and discrete valuation ring, Spec of ring. Number field, ring of integer, primes and ramifications. Class group, initeness of class number, Dirichlet's unit theorem. Global fields, local fields, valuations. Cyclotomic fields. Zeta functions and Lfunctions, class number formula. Adeles and ideles. **Course Reference**: 1. Number Fields, D. Marcus, Universitext, SpringerVerlag; 2. Problems in Algebraic Number Theory, E. Jody and M.Ram Murty, GTM 190, Springer Verlog; 3. Algebraic Number Theory, J.S. Milne, Course notes, available at http://www.jmilne.org; 4. Algebraic Number Theory, J. Neukirch, Grundlehren der Mathematischen Wissen schaften 322, SpringerVerlog; 5. Algebraic Number Theory, S. Lang, GTM 110, SpringerVerlog; 6. A course in Arithmetic, J P Serre, GTM 7, SpringerVerlog; 7. Algebraic Number Theory, R. Narasimhan et.al, TIFR Pamphlet, available at www.math.tifr.res.in/ publ/pamphlets/index.html; 8. Introduction to commutative algebra, M.F. Atiyah, and I.G. Macdonald, AddisonWesley Publishing Co.
MTH722A	INTRODUCTION TO HOMOTOPY THEORY		Content can be seen in the attched file
MTH732A	REPRESENTATIO N THEORY OF	3-0-0-0-9	Basic representation theory, Irreducible representation, Equivalence and unitary equivalence, Construction of new

	FINITE GROUPS		representation, Character of a representation, Schur's lemma and its applications, Schur's orthogonality relations, Schur's theory of characters, induced representations, Frobenius reciprocity, group algebra of S and A for small values of n.
MTH733	REPRESENTATIO N THEORY OF LINEAR LIE GROUPS	3-0-0--4	Representation theory of Compact groups; Peter Weyl Theorem. Linear LieGroups; The Exponential map, Lie Algebra, Invarient Differential Operaters.Representations of the group and its Lie Algebra. Fourier Analysis on SU (2) and SU (3). Representation theory of the heisenberg Group and some HarmonicAnalysis. Representation of the Euclidean Motion Group.
MTH733A	REPRESENTATIO N THEORY OF LINEAR LIE GROUPS	3-0-0-0-9	Representation theory of Compact groups; Peter Weyl Theorem, Linear Lie Group/ The Exponential map, Lie Algebra, Invarient Differential Operaters. Representations of the group and its Lie Algebra, Fourier Analysis on SU (2) and SU (3). Representation theory of the heisenberg Group and some Harmonic Analysis. Representation of the Euclidean Motion Group.
MTH734	BANACH ALGEBRAS, C* ALGEBRAS AND SPECTRAL THEORY	3-0-0--4	Elementary properties of Banach Algebras and examples; Ideals and quotients, the Spectrum, the Riesz Functional Calculas.Abelian Banach Algebras, C* Algebras; Representations of C* Algebras and the Gelfand Naimark Segal Construction.Normal Operators on Hilbert Space, Spectral measure and representation ofabelian C* algebras; The Spectral theorem; Some applications.
MTH734A	BRANCH ALGEBRAS, C* ALGEBRAS AND SPECTRAL THEORY	3-0-0-0-9	Elementary properties of Banach Algebras and examples; Ideals and quotients, the Spectrum, the Riesz Functional Calculas. Abelian Banach Algebras, C* Algebras; Representations of C* Algebras and the Gelfand Naimark Segal Construction. Normal Operators on Hilbert Space, Spectral measure and representation of abelian C* algebras; The Spectral theorem; Some applications.
MTH736	FOURIER ANALYSIS-I & DISTRIBUTION THEORY	3-0-0-0-4	Introduction, Test function spaces, Calculus with distributions, supports of distributions, Structure theorems, convolutions, Fourier transforms, L1, L2 theory of Fourier Transform, Tempered distributions, Paley Wiener theorem, wiener Tauberian theorem, Applications of distributions theory and Fourier transform to differential equations.
MTH736A	FOURIER ANALYSIS-I & DISTRIBUTION THEORY	3-0-0-0-9	Introduction, Test function spaces, Calculus with distributions, supports of distributions, Structure theorems, convolutions, Fourier transforms, L1, L2 theory of Fourier Transform, Tempered distributions, Paley Wiener theorem, wiener Tauberian theorem, Applications of distributions theory and Fourier transform to differential equations.
MTH751	ALGEBRA	3-0-0--4	Groups, Basic properties, Isomorphism theorems, Permutation groups, Sylow Theorems, Structure theorem for finite abelian groups, Rings, Integral domains, Fields, division rings, Ideals, Maximal ideals, Euclidean rings, Polynomial ring over a ring, Maximal & Prime ideals over a commutative ring with unity, Prime avoidance theorem and Chinese Remainder theorem, Field Extension, Cramer's

			rule, Algebraic elements and extensions, Finite fields. Determinants and their properties, Systems of linear equations, Eigen values and Eigen vectors, Caley Hamilton theorem, Characteristic and minimal polynomial, diagonalization, Vector spaces, Linear transformations, Inner product spaces.
MTH751A	ALGEBRA	3-0-0-0-9	Groups, Basic properties, Isomorphism theorems, Permutation groups, Sylow Theorems, Structure theorem for finite abelian groups, Rings, Integral domains, Fields, division rings, Ideals, Maximal ideals, Euclidean rings, Polynomial ringover a ring, Maximal & Prime ideals over a commutative ring with unity, Prime avoidance theorem and Chinese Remainder theorem, Field Extension, Cramer's rule, Algebraic elements and extensions, Finite fields. Determinants and their properties, Systems of linear equations, Eigen values and Eigenvectors, Caley Hamilton theorem, Characteristic and minimal polynomial, diagonalization, Vector spaces, Linear transformations, Inner product spaces.
MTH752	MATHEMATICAL METHODS	3-0-0--4	Calculus of Variations; Sturm Liouville Problem and Green's Function; Perturbation Methods and Similarity Analysis; Stability Theory.
MTH752A	MATHEMATICAL METHODS	3-0-0-0-9	Calculus of Variations; Sturm Liouville Problem and Green's Function; Perturbation Methods and Similarity Analysis; Stability Theory.
MTH753	ANALYSIS	3-0-0--4	Metric spaces, Open and closed sets, Compactness and connectedness, Completeness, Continuous functions (several variables and on metric spaces), uniform continuity C(X), X, compact metric space, Uniform convergence, compactness criterion, Differentiation, Inverse and Implicit fuction theorems. Riemann Integration, Lebesgue Integration, Lpspaces.Complex Analysis: Analytic functions, Harmonic conjugates, Cauchy theorems and consequences, Power series, Zeros of analytic functions, Maximum modulus theorem, Singularities, Laurent series, Residues. Mobius transformations. Hilbert spaces: Inner product, Orthogonality, Orthonormal bases, Riesz Lemma, The space L2 as a Hilbert space.
MTH753A	ANALYSIS	3-0-0-0-9	Metric spaces, Open and closed sets, Compactness and connectedness, Completeness, Continuous functions (several variables and on metric spaces), uniform continuity C(X), X, compact metric space, Uniform convergence, compactness criterion, Differentiation, Inverse and Implicit fuction theorems. Riemann Integration, Lebesgue Integration, Lpspaces. Complex Analysis: Analytic functions, Harmonic conjugates, Cauchy theorems and consequences, Power series, Zeros of analytic functions, Maximum modulustheorem, Singularities, Laurent series, Residues. Mobius transformations. Hilbert spaces: Inner product, Orthogonality, Orthonormal bases, Riesz Lemma, The space L2 as a Hilbert space.
MTH754	PROBABILITY THEORY	3-0-0-0-4	Algebras and sigma algebras; Measurable spaces; Methods of introducingprobability measures on measurable space;

			Random variables; Lebesgue integral;Expectation; Conditional probabilities and conditional expectations with respect to sigma algebras; Radon Nikodym theorem; Inequalities of random variables;Fubini’s theorem; Various kinds of convergence of sequence of random variables; Convergence of probability measures; Central limit theorem; delta method;Infinitely divisible and stable distributions; ZeroorOne laws; Convergence ofseries; Strong law of large numbers; Law of iterated logarithm; Matringales and their basic properties.
MTH754A	PROBABILITY THEORY	3-0-0-0-9	Algebras and sigma algebras; Measurable spaces; Methods of introducing probability measures on measurable space; Random variables; Lebesgue integral;Expectation; Conditional probabilities and conditional expectations with respect to sigma algebras; Radon Nikodym theorem; Inequalities of random variables; Fubini’s theorem; Various kinds of convergence of sequence of random variables; Convergence of probability measures; Central limit theorem; delta method;Infinitely divisible and stable distributions; ZeroorOne laws; Convergence ofseries; Strong law of large numbers; Law of iterated logarithm; Matringales and their basic properties.
MTH755	STATISTICAL INFERENCE	3-0-0--4	Population and samples; Parametric and nonparametric models; Exponential and location scale families; Sufficiency and minimal sufficiancy; Complete statistics;Unbiased and UMVU estimation; Asymptotically unbiased estimators; Method of moments; Bayes estimators; Invariance; Minimaxity and admissibility; The method of maximum likelihood; Asymptotically efficient estimation; Variance estimation; The jacknife; The bootstrap; The NP lemma; MLR; UMP tests forone and two sided hypotheses; Unbiased and similarity; UMPU tests in exponential families; Invariance and UMPI tests; LR tests; Asymptotic tests based on likelihoods; Chisquare tests; Bayes tests; Pivotal quantities; Inverting acceptance regions of tests; The Bayesian confidence interval; Prediction sets; Length of confidence intervals; UMA and UMAU confidence sets; Invariant confidence sets.
MTH755A	STATISTICAL INFERENCE	3-0-0-0-9	Population and samples; Parametric and nonparametric models; Exponential and location scale families; Sufficiency and minimal sufficiancy; Complete statistics; Unbiased and UMVU estimation; Asymptotically unbiased estimators; Method of moments; Bayes estimators; Invariance; Minimaxity and admissibility; The method of maximum likelihood; Asymptotically efficient estimation; Variance estimation; The jacknife; The bootstrap; The NP lemma; MLR; UMP tests forone and two sided hypotheses; Unbiased and similarity; UMPU tests in exponential families; Invariance and UMPI tests; LR tests; Asymptotic tests based on likelihoods; Chisquare tests; Bayes tests; Pivotal quantities; Inverting acceptance regions of tests; The Bayesian confidence interval; Prediction sets; Length of confidence intervals; UMA and UMAU confidence sets; Invariant confidence sets.

MTH761	VECTOR BUNDLES AND CHARACTERISTI C CLASSES	3-0-0-0-4	Smooth Manifolds, Vector bundles, Constructing New vector bundles Out of Old. Grassmann Manifolds and Universal bundles, The classification of vector bundles. Characteristic- classes for vector bundles, Stiefel Whitney classes of manifolds, Characteristic numbers of manifolds, Thom spaces and the Thom isomorphism theorem, The construction of Stiefel Whitney classes, Chern, Pontryagin, and Euler classes. **Course Reference**: 1.J. P. May. A concise course in Algebraic Topology. Chicago Lectures in Mathematics. University of Chicago Press, Chicago, IL, 1999, pp.; 2. John W. Milnor and James D. Stasheff. Characteristic classes. Annals of Mathematics Studies, No. 76. Princeton University Press, Princeton, N. J.; University of Tokyo Press, Tokyo, 1974.
MTH781	STATISTICAL PATTERN RECONGNITION	3-0-0-0-4	Introduction to pattern recongnition supervised and unsupervised classification. Dimension reduction techniques: principal component analysis, multidimensional scaling features for maximum linear separation projection pursuit. Parametric methods for discriminant analysis: Fisher’s linear discriminant function. Linear and quadratic discriminant analysis regularized discriminant analysisi. Linear and nonlinear support vector machines. Cluster analysis: hierarchical and nonhirerarchical techniques classification using Gaussian mixtures. Data depth: different notions of depth, concept of multivariate median, application of depth in supervised and unsupervised classification.
MTH781A	STATISTICAL PATTERN RECONGNITION	3-0-0-0-9	Introduction to pattern recongnition supervised and unsupervised classification. Dimension reduction techniques: principal component analysis, multidimensional scaling features for maximum linear separation projection pursuit. Parametric methods for discriminant analysis: Fisher’s linear discriminant function. Linear and quadratic discriminant analysis regularized discriminant analysisi. Linear and nonlinear support vector machines. Cluster analysis: hierarchical and nonhirerarchical techniques classification using Gaussian mixtures. Data depth: different notions of depth, concept of multivariate median, application of depth in supervised and unsupervised classification.
MTH785	ECONOMETRIC THEORY	3-0-0--4	Multiple linear model, estimation of parameters under spherical and nonsphericaldisturbances by least squares and maximum likelihood methods, testsof hypothesis, R2 and adjusted R2. Prediction, within and outside sample predictions. Problem of structural change, tests for structural change. Use of dummy variable. Specification error analysis related to explanatory variables, inclusion and deletion of explanatory variables. Idea of Stein rule estimation. Exact and stochastic linear restrictions, restricted and mixed regression analysis. Multicollinearity, problem, implications and tools for handling the problem, ridge regression. Hetero skedasticity, problem and test, estimation under Hetero skedasticity. Autocorrelation, DurbinWatson test. Errors invariables, inconsistency of least squares method, methods of consistent estimation,

			instrumental variable estimation. Seemingly unrelated regression equation model, least squares, generalized least squares and feasible generalized least squares estimators. Simultaneous equations model, structural and reduced forms, rank and orderconditions for identifiability, indirect least squares, two stage least squares and imited information maximum likelihood methods of estimation. Additional topics like as Panel data models and unit roots & cointegration.
MTH799	RESEARCH	----	Ph. D. Research
MTH800	RESEARCH	----	RESEARCH
SE351	LINEAR ALGEBRA	3-1-0-0-4	Fields and linear equations. Vector spaces. Linear transformations and projections, relations, etc. Determinants. Elementary canonical forms: diagonalization, triangulation, primary decomposition etc. Secondary decomposition theorem, Rational canonical forms, Jordan canonical forms and some applications. Inner product spaces, Self adjoint, Unitary and normal operators, Orthogonal projections. Bilinear forms, Symmetric, Skewsymmetric, Positive and semipositive formsetc.
SE352	DISCRETE MATHEMATICS	3-1-0-0-4	Permutations and combinations and basic definitions. Generating functions. Poly as enumeration theory. Recurrence relations. Principle of inclusion and exclusion. Balanced incomplete block design. Difference sets. System of distinct representatives. Orthogonal Latin squares. Hadamard matrices.
SE353	BASIC STRUCTURES OF MATHEMATICS	3-1-0--4	Finite and Infinite Sets: Finite sets, Countable sets, Uncountable sets. Groupsand Symmetry: Groups, Subgroups, Lagrange theorem, Normal subgroups, Quotient groups, Group actions, Homomorphisms, Group of symmetry rigidmotion group, finite subgroups of the rotation group, symmetric group. MetricSpaces: Open sets, Closed sets, Sequences, Continuity, Complete metric spaces, Contraction principle and applications, Connectedness and compactness. Fractals: Metric space of fractals and its completeness, Iterated function systems, Attractor, Algorithms to generate fractals. Topology of Surfaces: Eulers theorem, Construction of surfaces by identification: Torus, mobius strip, Klein bottle.
SE354	MATHEMATICAL LOGIC	3-1-0-0-4	Formal theories, consequence and deduction. Classical Propositional Calculus: Syntax, truth, validity, Adequacy of connectives, normal forms, applications tocircuit design, Axiomatic treatment, deduction theorem, derived rules ofinference, Soundness, Independence of axioms, Consistency, completeness, Completeness w.r.t. Boolean algebras, Computer assisted formal proofs: tableaux, resolution. Classical first order theories: Syntax, satisfaction, truth validity, Axiomatic treatment, Equality, Examples of firstorder theories: Peano arithmetic, Groups, Orderings, Basis of axiomatic set theory, Deduction theorem, derivedrules of inference, soundness, Consistency, completeness, Lowenheim Skolem theorems,

			compactness, Firstorder theories with equality, Decidability, Computer assisted formal proofs: tableaux, resolution. Godels incompleteness theorems. Examples of other/nonclassical logics. Other proof techniques natural deduction, sequent calculus.
SE356	OPERATIONS RESEARCH - I	3-1-0-0-4	Linear Models: Formulation and Examples, Basic Polyhedral Theory Convexity,Extreme points, Supporting hyperplanes etc, Simplex Algorithm Algebraic and Geometrical approaches, Artificial variable technique, Duality Theory: Fundamental theorem, Dual simplex method, Primaldual method, Sensitivity Analysis, Bounded Variable L.P.P. Transportation Problems: Models and Algorithms, Network Flows:Shortest path Problem, MaxFlow problem and Mincost Flow problem, Dynamic Programming: Principle of optimality, Discrete and continuous models.
SE358	REGRESSION ANALYSIS	3-1-0-0-4	Generalized Inverses, Cochrans theorem, Gauss Markov Setup, Least squares estimators with restriction on parameters, Test of Hypothesis of linear parameteric function, ANOVA, power of tests, Confidence Intervals and Regions, Multiple comparison, Linear, Polynomial and Multiple Regression, Residual Analysis, Multico llinearity, Ridge Regression and Principal Component Analysis, Subset Selection, Nonlinear Regression.
SE359	APPLIED STOCHASTIC PROCESSES	3-1-0-0-4	Definition and classification of general stochastic processes. Markov Chains: definition, transition probability matrices, classification of states, limiting properties. Markov Chains with Discrete State Space: Poisson process, birth and death processes. Renewal Process: renewal equation, mean renewal time, stopping time. Markov Process with Continuous State Space: Introduction to Brownian motion.
SE360	MATHEMATICAL METHODS	3-1-0-0-4	Multiple Integral Theorems and their Applications: Greens theorem, Stokes theorem and Gauss divergence theorem. Integral Transforms: Fourier, Fouriersine/cosine and Hankel Transforms with their inverse transforms (properties, convolution theorem and application to solve differential equation). Perturbation Methods: Perturbation theory, Regular perturbation theory, Singular perturbation theory, Asymptotic matching. Calculus of Variation: Introduction, Variational problem with functionals containing first order derivatives and Euler equations. Functionals containing higher order derivatives and several independent variables. Variational problem with moving boundaries. Boundaries with constraints. Higherorder necessary conditions, Weirstrass function, Legendres and Jacobis condition. Existence of solutions of variational problems. RayleighRitz method, statement of Ekelands variational principle and applications.
SE361	STATISTICAL SIMULATION & DATA ANALYSIS	3-1-0-0-4	Simulation of random variables from discrete, continuous, multivariate distributions and stochastic processes, MonteCarlo methods. Regression analysis, scatterplot, residual analysis. Computer Intensive Inference Methods JackKnife, Bootstrap, cross validation, Monte Carlo methods and permutation tests. Graphical representation of

			multivariate data, Cluster analysis, Principal component analysis for dimension reduction.
SE363	FINITE ELEMENT METHOD	3-1-0--4	Introduction and motivation, Weak formulation of BVP and Galerkin approximation, Piecewise polynomial spaces and finite element method, Computer implementation of FEM, Results from Sobolev spaces, Variational formulation of elliptic BVP, LaxMilgram theorem, Estimation for general FE approximation, Constructionof FE spaces, Polynomial approximation theory in Sobolev spaces, Variational problem for second order elliptic operators and approximations, Mixed methods, Iterative techniques.
SE364	MATHEMATICAL MODELING	3-1-0--4	Elementary mathematical models. Role of mathematics in problem solving. Concepts of mathematical modeling. System approach. Formulation. Analysis of models. Sensitivity analysis & parameter estimation. Design of experiment, Validation. Simulation approach. Pitfalls in modeling. Illustrations.

MATERIALS AND METALLURGICAL ENGINEERING

Template?

DEPARTMENT OF MME			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
MME100	INTRODUCTION TO PROFESSION	2-0-0-0-0	Historical aspects of various materials, including some landmarks; Natural resources of materials; Cost, economics, energy, environmental and political issues relating to materials industry and applications; Importance of materials and their properties, performance and manufacturing processes in the development and growth of automotive, aerospace and railway sectors, electrical, electronic and telecommunication equipment/systems, energy sector, military hardware,structural and general engineering applications, biomedical/implant materials etc.; Demonstrations/film shows related to selected materials and their characterization, properties and processing.
MME200	THERMODYNAMICS OF MATERIALS	3-1-0-0-4	Heterogeneous and homogeneous systems, extensive and intensive properties,simple equilibrium; First Law of thermodynamics, constant volume and constant pressure processes; Spontaneous processes, entropy and quantification of irrversibility, properties of heat engines, thermodynamic temperature scale, Second Law of thermodynamics, criterion for equilibrium, Entropy and disorder,most probable microstate, configurational entropy and thermal entropy; auxiliary functions, Maxwell's relations, GibbsHelmholtz equation; Third Law of thermodynamics; variation of Gibbs energy with temperature and pressure, Clausius Clapeyron equation; thermodynamic properties of mixtures of ideal andimperfect gases; reactions in gas mixtures; reactions of pure condensed phaseswith gas mixtures standard Gibbs energy of reactions, Ellingham diagrams;Raoulfs and Henrys Law, activity of a component, Gibbs Duhem equation, nonidealsolutions, regular solutions, quasichemical model of solution, activity and alternative standard states; reaction equilibrium in condensed system, Gibbsphase rule, binary systems involving compound formation, solubility of gasesin metals, formation of oxide phases of variable

			composition; relation between chemical and electrical driving forces, Nernst equation, concentration and formation cells, Pourbaix diagrams; thermodynamics of Point Defects.
MME210	METALLURGICAL KINETICS	3-1-0-0-4	Thermodynamics vs. kinetics, homogeneous and heterogeneous reactions;Chemical Reaction Controlrate equation, reaction rate constant, reaction order,nonelementary reactions; Solid State Diffusion Ficks Law, mechanism ofdiffusion, uphill diffusion, Kirkendall effect, steady and transient diffusion;External Mass Transfer fluid flow and its relevance to mass transfer, general mass transport equation, concept of mass transfer coefficient, models of mass transfer film theory and Higbies penetration theory; Internal Mass Transfer Ordinary and Knudsen diffusion, Mass transfer with reaction; Adsorption physical adsorption vs. chemisorption, adsorption isotherms; Langmuir, BET, adsorption as the rate limiting step; gasification of C by CO2, dissolution of N2 in molten steel, porous solids, specific surface area and pore size distribution; Reactor Design batch vs. continuous reactors, ideal stirred tank and plug flow reactors,mass balance in ideal reactors, residence time distribution; models of industrial reactors; Electrochemical Kinetics concept of polarization, activation over potential, ButlerVolmer and Tafels equation, applications in electro deposition and corrosion,concentration over potential, limiting current; electrowinning and corrosion.
MME250	MATERIALS CHARACTERIZATION	3-0-3-0-5	Chemical bonding, fundamentals of crystallography, reciprocal lattice, structures in metals, inorganic compounds, polymers, silicates and glasses, stereographic projections; Production, characterization, and interaction of Xrays with matter,Braggs Law and Laues equations, Ewalds construction, diffraction techniques and applications; Optical principles of microscopy resolution, magnification, depth of focus; electron diffraction, imaging (various contrasts), determination of crystal structure, burgers vector, electron beam specimen interactions andother applications of Transmission Electron Microscopy; Applications of ScanningElectron Microscopy and, Electron Probe Micro Analyser; Principles of Quantitative Microscopy: volume density, surface density, length density, numerical density,particle and grain size; Overview of other characterization techniques such asAuger electron spectroscopy, Scanning Tunneling Microscopy, Atomic Force Microscopy.
MME310	MECHANICAL BEHAVIOUR OF MATERIALS	3-1-0-0-5	Stress tensor and stress transformation equations, Principal stresses; Strain tensor and strain transformation equations; Isotropic and anisotropic elasticity, elastic strain energy; Yield criteria and constitutive relationships; Work hardening,plastic instability and its significance; Crystallographic aspects

			of plastic deformation; Dislocation theory edge, screw and mixed dislocations, resistance to dislocation motion and elastic properties of dislocations, dislocation interactions, multiplication and dissociation; Strengthening mechanisms; Creep characteristics of creep curve and steady state creep, mechanisms and creep mechanism maps,creep under complex stress states, prediction of long time properties; Fracture toughness and fatigue Griffiths crack theory, energy release rate analysis,modes of loading, stress analysis of cracks, fracture toughness, Low and High cycle fatigue, Fatigue crack initiation and propagation, structural aspects offatigue, fatigue under complex stress states, environmental assisted cracking and fatigue; Some case studies related to design.
MME320	PRINCIPLES OF METAL EXTRACTION AND REFINING	3-1-0-0-4	History and importance of metal extraction; Introduction of mineral dressing: Communition, Tabling, Jigging and flotation; Metallurgical fuels and the energy scenario; Pyrometallurgical operations roasting, agglomeration, smelting, refining and secondary refining; Principles of Hydro Metallurgy; Principles of Electro Metallurgy Aqueous solution and fused salts; Flow sheet design of importantnon ferrous metals based on materials and heat balance.
MME330	PHASE EQUILIBRIA IN MATERIALS	3-1-0-0-5	Phase rule, lever rule and Free energy of phase mixtures; Binary isomorphous systems Equilibrium solidification, nonequilibrium solidification, dendritic growth, coring, CuNi alloys and Zone refining; Binary Eutectic and Peritectic Systems solidification of eutectic, hypoeutectic, and hypereutectic alloys; solidification of peritectic, hypoperitectic, and hyperperitectic alloys; morphologies of eutectic systems, Binary Monotectic and Syntectic Systems; Stability of regular solution and miscibility gas, intrinsic stability of solutionand spinodal; HumeRothery rules and intermediate phases e.g., laves, sigma, electron compounds; Binary eutectoid, peritectoid, metatectic and monotecticsystems; Iron carbon phase diagram and microstructures of plain carbon steeland cast iron: nonequilibrium structures; Binary ceramics systems: SiO2AbOa,NiOMnO, etc.; Ternary phase diagrams Gibbs triangle, isothermal and vertical sections, polythermal projections, twophase equilibrium, concept of tie lines,rules for construction of tie lines, three phase equilibrium, concept of tietriangle,four phase equilibria; Multicomponent alloy systems: Stainless steels, highspeed steels, Hadfield steels, superalloys, light metal alloys, refractory systems, (AbOaSiO2MgO) , sialanes.
MME331	PROCESS METALLURGY LAB.	0-0-3-0-2	Laboratory techniques of temperature and flow rate measurement and calibration: Experiments on Mineral Engineering, Metallurgical Thermodynamics and Kinetics, Fuels and Furnaces, Iron making, steelmaking, pyro, hydro, electrometallurgy in

			extraction of nonferrous metals and metallurgical analysis.
MME340	PHASE TRANSFORMATIONS IN MATERIALS	3-0-0-0-4	Thermodynamic order of transformations; Theory of nucleation Kinetics of homogeneous, transient and heterogeneous nucleation; Theory of Thermally Activated Growth: Interface controlled growth, Diffusion controlled growth,Interface instability and Widmanstatten growth, Eutectoid growth, Discontinuous precipitation, Massive transformation; Transformation Kinetics Johnson Mehlequation, Avrami model, Transformation kinetics in diffusion controlled transformations, Isothermal and continuous cooling transformation diagrams; Precipitation and Particle Coarsening; Kinetics of recrystallization, Theory ofgrain growth, Effect of second phase particles; Martensitic transformation Nature of martensitic transformations, Bain distortion, Nucleation, and growth of martensite, Athermal, isothermal and burst transformations, Thermoeleastic martensitie; Spinodal Decomposition Diffusion equation in spinodal region, Effect of gradient energy and elastic strain energy; Solidification Nature andgrowth of solidliquid interfaces, Rapid solidification, Glass transition, metallic glasses; Heat Treatment IT and CCT Diagrams in steels, quench hardening and tempering of martensite, hardenability of steels, surface hardening processes,tool steels and their heat treatments, heat treatment of cast irons, heat treatment of Nibase super alloys and Ti alloys, Thermo mechanical treatments.
MME350	IRON AND STEELMAKING	3-1-0-0-4	Refractories for iron and steel; Design and profile of an iron blast furnace andits auxiliaries; Performance evaluation of bast furnace Iron ore reduction, fuelrate calculations, BF aerodynamics and hot metal quality control; Energy and materials balance calculations in steelmaking processes; Physical chemistry of steel making and secondary steel making deoxidation, ladle and tundish metallurgy, ingot and continuous casting of steel; Emerging trends in iron and steel making.
MME370	FUNDAMENTALS OF MATERIALS PROCESSING	3-0-0-0-4	Overview of various processing methods for materials; microstructural evolutionduring solidification and effect of cooling rate on cast microstructures, micro and macro segregation in alloys, directional solidification, rapid solidification;Elements of casting mold design solidification shrinkage and its role in riserdesign, fluid flow fundamentals and metal fluidity, elements of mold design; Fundamentals of deformation processing State of stress during various metal working operations, friction and its role in bulk metal forming operations, microstructural evolution during deformation processing, workability of metals, superplastic forming; Metal flow and aspects of design during bulk forming operations, elementary load calculations during various bulkmetal working operations; Sheet metal forming State of stress during sheet metal forming processes,

			forming limit diagram, ehancement of sheet metal formability; Fundamentals of powder processing Basics of metal and ceramic powder productions and characterization, design aspects during powder consolidation; solid and liquid state sintering, driving force and mechanism of si ntering ,selection of sintering atmosphere for different systems, characterization ofsintered products, full density processing.
MME390	INDUSTRIAL TOUR	0-0-0-0-0	Visit to industries in and around Kanpur or elsewhere primarily of interest toMaterials and Metallurgical Engineering.
MME410	ELECTRONIC & MAGNETIC PROPERTIES OF MATERIALS	3-0-0-0-4	DC conductivity of metals, Hall effect and magneto resistance, AC conductivity of metals, thermal conductivity and specific heat of metals, Thermopower of metals; Review of quantum mechanics and free electron theory, failures of free electron theory and introduction to the role of lattice; Review of reciprocal lattice,Brilouin zone, Free electron band diagrams, potential in a crystal, electrondynamics and concept of holes, conductivity in relation to band structure, band structures of metals and semiconductors; empirical estimates of conductivity in metals and alloys; Semiconductors band diagrams, direct and indirect bandgap, applications of semiconductors; Degenerate and non degenerate semiconductors, intrinsic and extrinsic semiconductors, determination of dopantlevels and mobility measurements; Ionic conduction review of defect equilibriumand diffusion mechanisms, theory of ionic conduction, conduction in glasses,effect of stoichiometric and extrinsic defects on conduction, applications insensors and batteries; Dielectric Materials Dielectric constant and polarization,linear dielectric materials, capacitors and insulators, polarization mechanisms,nonlinear dielectrics pyro, piezo and ferroelectric properties, hysterisis and ferroelectric domains and applications; Optical Materials electron hole recombination, solidstate LEDs, lasers and IR detectors, band gap engineering; Light interaction with materials transparency, translucency and opacity, refraction and refractive index, reflection, absorption and transmission; Magnetic field,flux density, susceptibility and permeability; Orbital and spin, permanent magnetic moment of atoms, diamagnetism, paramagnetism and Pauli paramagnetism, ferro, antiferro and ferri magnetism, Fe, Co and Ni and alloy additions, ferrites, magnetic hysterisis, soft and hard magnet materials.
MME415	PHYSICAL METALLURGY LAB	0-0-3-0-2	Laboratory techniques for studying phase transformations in materials, recrystallization and grain growth, eutectoid transformations in steels, hardenability, tempering of martensite; resistivity of metals, conductivity of semiconductors, conduction in ionic solids, dielectric measurements in BaTiO3, reflection, absorption and transmission measurement

			on various metals.
MME420	HISTORY OF SCIENCE AND TECHNOLOGY OF METALLURGY	3-0-0--4	Mining, Smelting, Alloying (mainly copper tin), Metal forming: forging, casting Origins of metallurgy in Balkans, Near and Middle East; Metallurgy in Prehistoric World, Iron and Steel, Silver, Lead, Brass, Zinc, Gold and Platinum, Decoration, Plating, Metal Fakes and Forgeries, Surface Treatment, Metallurgy of India, Metallurgy in Asia, Metallurgy of Greece and Rome, Metallurgy in Europe and the Middle East, Metallurgy of the Americas and Africa.
MME424	MODELLING OF STEELMAKING PROCESSES	3-0-0--4	Brief review of fundamentals of steel making processes: Brief review of fundamentals of transport processes: Mathematical modeling fundamentals: Successful modeling examples.
MME425	PROCESS PLANT DESIGN FOR METT. ENGG. OPERATIONS	3-0-0--4	Identification of process flow sheet: Preliminary estimate of resources andfacilities: Materials and energy balance, detailed plant flow sheet: Equipmentselection and specification, economic selection and specification: environmental impact analysis: Report presentation, case studies of typical metallurgical plant operation.
MME430	FURNANCE TECHNOLOGIES	3-0-0--4	Definition and classification of furnaces; Principles of heat generation in fuelfired furnaces and combustion, Flame temperature, Burners for liquid and gaseous fuels, Movement of gases in furnaces, ducts and chimneys, Heat generation in electric furnaces, resistance, induction, are, plasma etc. Metallic and nonmetallic heating elements. Furnaces, resistence, induction, are, plasmaetc. Metallic and nonmetallic heating elements. Furnace construction materials: Manufacture and uses of different types of refractories and insulators, critical insulation thickness, criteria of section of refractory material. Heat balance of a furnace and thermal efficiency, Waste heat recovery systems and their designs, Atmosphere in furnaces. Fuel economy measures in furnaces. Constructional, operational and design features of different types of furnaces like soaking pits, pusher type, walking beams, forging furnaces etc.

NUCLEAR ENERGY AND TECHNOLOGY

NUCLEAR ENGINEERING & TECHNOLOGY

BT/BS-MT (PG Part – Category – B) *(from other departments)*				Template No.NET-1
	SEMESTER			
COURSES	7th	8th	9th	10th
	NT602A [09]	NT621A [09]	M.Tech. Thesis [36]	M.Tech. Thesis [36]
	NT611A [09]	NT614A [09]	-	-
	-	DE PG-1 [09]		
		DE PG-2 [09]		
	18	36	36	36

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Component : 54 Credits

Thesis Component : 72 Credits

REMARKS:

1) At least one DE PG should be opted from NET courses.
2) All courses to be taken with the permission of Supervisor/ DUGC Convener.
3) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech. part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
4) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the dual degree programme. These will be waived from the parent department's BT/BS programme requirements and counted towards PG requirements.

DEPARTMENT OF NE Tech.

Courses ID	Course Title	Courses ID	Content
NE620A	RADIATION INTERACTION, DETECTION, AND SHIELDING-THEORY ON NUCLEAR MEASUREME	NE620A	Applications of Radiation. Half Life Determination. Radiation Dose Levels and Calculation: Inverse Square Law Verification, ALARA Principle, Linear no threshold model. Basic Principles of Radiation Detection. Gamma Ray Interactions: photoelectric, Compton scattering, pair production Empirical calculation of cross sections, Linear Attention Coefficient Measurement. Evaluation of GM Detector Characteristics: Plateau determination, Dead time calculations, paralyzable and nonparalyzable detectors. Measurements and Counting Statistics for Error Evaluation Limits. Ionizing radiation and detection, Neutron and special nuclear material (SNM) detection for security applications. Mechanisms of neutron interaction: capture, scientillation etc. Scintillation detectors, Capture detectors, Fission chambers. Semiconductor Detectors. Pulse shaping and signal processing. Radiation detection and shielding methods for safety at various nuclear facilities. Measuring gamma dose and shielding calculations. Measuring neutron spectrum and dose and shielding calculations. Measuring other forms of radiation, dose and shielding calculations. Principles of particle accelerator and measurements on the 1.7 MeV TANDETRON* OR Instrumentation and controls used in existing and advanced nuclear power plants*

NT602	NUCLEAR AND REACTOR PHYSICS	NT602	Introduction to quantum mechanics, Schrodinger equation and its solution by separation of variables. Potential well, quantum states. Nuclear charge, radius and mass. Binding energy. Nuclear forces and the deuteron problem. Semiempirical mass formula. Energetics of nuclear stability. Reaction channels, Compound nucleus. Energy dependence of neutron cross sections and Brecitwigner formula. The fission process. Neutron diffusion theory showing down length. Critical mass and size. Numerical criticality search. Four factor formula. Energy dependent diffusion. Multigroup diffusion, group constants and matrix formulation. Two group analysis. Age theory. Slowing down theory.
NT602A	NUCLEAR AND REACTOR PHYSICS	NT602A	Introduction to quantum mechanics, Schrodinger equation and its solution by separation of variables. Potential well, quantum states. Nuclear charge, radius and mass. Binding energy. Nuclear forces and the deuteron problem. Semiempirical mass formula. Energetics of nuclear stability. Reaction channels, Compound nucleus. Energy dependence of neutron cross sections and Brecit wigner formula. The fission process. Neutron diffusion theory showing down length. Critical mass and size. Numerical criticality search. Four factor formula. Energy dependent diffusion. Multigroup diffusion, group constants and matrix formulation. Two group analysis. Age theory. Slowing down theory.
NT611	NUCLEAR POWER ENGINEERING I	NT611	Types of nuclear reactors. Heat generation in fuel elements and temperature distributions. Heat removal, Reactor coolants. Single phase and two-phase heat transfer. Boiling and flow regimes. Heat transfer and fluid flow correlations. Pressure drops due to friction and pumping power. Reactor core
NT611A	NUCLEAR POWER ENGINEERING I	NT611A	Types of nuclear reactors. Heat generation in fuel elements and temperature distributions. Heat removal, Reactor coolants. Single phase and two-phase heat transfer. Boiling and flow regimes. Heat transfer and fluid flow correlations. Pressure drops due to friction and pumping power. Reactor core.
NT614	NUCLEAR POWER ENGINEERING II	NT614	Introduction to control theory. Point reactor kinetics with introduction to feedback effects. Nonlinear effects. Shielding. Introduction to reactor reliability and safety analysis. Radioactive waste disposal. Economics of nuclear power. Introduction to nuclear fuel cycles.
NT614A	NUCLEAR POWER ENGINEERING II	NT614A	Introduction to control theory. Point reactor kinetics with introduction to feedback effects. Nonlinear effects. Shielding. Introduction to reactor reliability and safety analysis. Radioactive waste disposal. Economics of nuclear power. Introduction to nuclear fuel cycles.

NT615	NUCLEAR POWER ENGINEERING III	NT615	Health Physics: introduction, radiation protection, regulatory aspects, radiation biology, operational radiation protection, radiation protection monitoring. Process Instrumentation and Control: basic concepts, sensing and transmission/receiving of temperature, flow, liquid level, pressure, force, viscousity, humidity. Nuclear Materials: fabrication and properties of zircaloy, metallic fuels, ceramic fuels, applications. Nuclear Chemistry: role of chemistry in nuclear engineering, chemical processes in the nuclear fuel cycle, production of uranium, plutonium, thorium, heavy water, water treatment, corrosion, decontamination.
NT620A	RADIATION INTERACTION, DETECTION, AND SHIELDING-THEORY ON NUCLEAR MEASUREME	NT620A	Applications of Radiation. Half Life Determination. Radiation Dose Levels and Calculation: Inverse Square Law Verification, ALARA Principle, Linear no threshold model. Basic Principles of Radiation Detection. Gamma Ray Interactions: photoelectric, Compton scattering, pair production Empirical calculation of cross sections, Linear Attention Coefficient Measurement. Evaluation of GM Detector Characteristics: Plateau determination, Dead time calculations, paralyzable and nonparalyzable detectors. Measurements and Counting Statistics for Error Evaluation Limits. Ionizing radiation and detection, Neutron and special nuclear material (SNM) detection for security applications. Mechanisms of neutron interaction: capture, scientillation etc. Scintillation detectors, Capture detectors, Fission chambers. Semiconductor Detectors. Pulse shaping and signal processing. Radiation detection and shielding methods for safety at various nuclear facilities. Measuring gamma dose and shielding calculations. Measuring neutron spectrum and dose and shielding calculations. Measuring other forms of radiation, dose and shielding calculations. Principles of particle accelerator and measurements on the 1.7 MeV TANDETRON* OR Instrumentation and controls used in existing and advanced nuclear power plants* 1. G.F. Knoll, Radiation Detection and Measurements, John Wiley & Sons, Hoboken, New Jersey (2010).2. S.S. Kapoor and V.S. Ramamurthy, Nuclear Radiation Detectors, Wiley Eastern Limited (1986).3. K.S. Ram, Nuclear Measurement and Techniques, Affiliated EastWest Press, New Delhi (1986).
NT621	NUCLEAR MEASUREMENTS LABORATORY	NT621	Biological effects of radiation; Radiation monitoring; GM Counter characteristics, counting statistics. Scintillation detectors and gamma spectrometry. Multichannel analysis. Semiconductor detectors for alpha and gamma spectrometry. Coincidence measurements. BF 3 counters. Foil Activation. Cadmium ratio measurements. Neutron diffusion length and age measurements. Experiments using Van de Graaff. Radioisotope applications, Computer

			simulation studies.
NT621A	NUCLEAR MEASUREMENTS LABORATORY	NT621A	Biological effects of radiation; Radiation monitoring; GM Counter characteristics, counting statistics. Scintillation detectors and gamma spectrometry. Multichannel analysis. Semiconductor detectors for alpha and gamma spectrometry. Coincidence measurements. BF 3 counters. Foil Activation. Cadmium ratio measurements. Neutron diffusion length and age measurements. Experiments using Van de Graaff. Radioisotope applications, Computer simulation studies.
NT633	NUCLEAR FUSION	NT633	Basic physics of fusion reactions, thermonuclear cross sections. Radiation losses: bremsstrahlung and cyclotron radiation. Energy balance: Lawson criterion, neutronnics in a fusion reactor. Plasma confinement: Pinch effect, stellarator and magnetic mirrors. Plasma heating ohmic and adiabatic compression: Tokamaks. Inertial confinement of plasma micro explosion and laser fusion.
NT641	INTRODUCTION TO COMPUTERIZED TOMOGRAPHY	NT641	Overview, medical imaging, nondestructive testing, radiographic techniques, various applications, data collection, design of CT scanners for materials testing, flow measurement, related instrumentation, Radons inversion formula, central slice theorem, fan beam inversion, filter functions, convolving functions transform methods, series expansion methods, convolution algorithms, error estimates, direct theorems, inverse theorems.
NT641A	INTRODUCTION TO COMPUTERIZED TOMOGRAPHY	NT641A	Overview, medical imaging, nondestructive testing, radiographic techniques, various applications, data collection, design of CT scanners for materials testing, flow measurement, related instrumentation, Radons inversion formula, central slice theorem, fanbeam inversion, filter functions, convolving functions transform methods, series expansion methods, convolution algorithms, error estimates, direct theorems, inverse theorems.
NT642	NON-DESTRUCTIVE EVALUATION	NT642	Introduction, various NDE techniques ultrasonics, eddy current, magnetic flux leakage, radiography, optical, tomographic extensions of classical NDE/NDT methods Radon inversion, data collection mechanisms, applications in industrial situations.
NT642A	NON-DESTRUCTIVE EVALUATION	NT642A	Introduction, various NDE techniques ultrasonics, eddy current, magnetic flux leakage, radiography, optical, tomographic extensions of classical NDE/NDT methods Radon inversion, data collection mechanisms, applications in industrial situations.
NT651	FAST REACTOR TECHNOLOGY	NT651	Introduction, Core design, Fuel element design, Fuel management, Heat transport systems, Steam generators, IHX design, Sodium pumps & piping, Instrumentation& controls, safety, extractive and physical metallurgy of nuclear materials, Metallic

			fuels, cladding, post irradiation examination, fabrication of fuel, Steels for nuclear environment, advanced NDT techniques, corrosion.
NT651A	FAST REACTOR TECHNOLOGY	NT651A	Introduction, Core design, Fuel element design, Fuel management, Heat transport systems, Steam generators, IHX design, Sodium pumps & piping, Instrumentation& controls, safety, extractive and physical metallurgy of nuclear materials, Metallic fuels, cladding, post irradiation examination, fabrication of fuel, Steels for nuclear environment, advanced NDT techniques, corrosion.
NT652	NUCLEAR FUEL CYCLE	NT652	Introduction, nuclear fuels, uranium technology, xirconium process, fabrication of fuel assemblies, PWR fuel, mixed oxide fuel, irradiated fuel, reprocessing, radioactivity, contamination, waste management, enrichment of uranium, thorium cycle, fast reactor fuel cycle and fuel fabrication, environmental impact and safety.
NT699	M TECH THESIS	NT699	M. Tech. Thesis
NT799	PHD THESIS	NT799	Ph. D. Thesis

PHOTONIC SCIENCE AND ENGINEERING

PHOTONICS SCIENCE AND ENGINEERING PROGRAMME

BT/BS – MT (PG Part – Category B) (*from other departments*)			Template No. LTP-1	
COURSES	7th	8th	9th	10th
	PG-1 [09] (PSE601A)	PG-3 [09] (PSE604A)	M.Tech. Thesis [36]	M.Tech. Thesis [36]
	PG-2 [09] (PSE602A)	PG-4 [09] (PSE605A)		
	18	18	36	36

MINIMUM CREDIT REQUIREMENT IN M.TECH PART FOR GRADUATION:

PG Component : 36 Credits
Thesis Component : 72 Credits

REMARKS:

1) All courses to be taken with the permission of Supervisor/ DUGC Convener.
2) Course credits and Thesis credits mentioned under the dual degree template are only for the M.Tech. part of the programme. In addition to these credits, students are required to follow and complete all their graduation requirements for their UG programme.
3) Upto 36 OE credits may be used from the parent department's BT/BS minimum requirements to fulfil requirements for the dual degree programme. These will be waived from the parent department's BT/BS programme requirements and counted towards PG requirements.

DEPARTMENT OF PSE

Course ID	Course Title	Credits L-T-P-D-[C]	Content
PSE601	INTRODUCTION TO PHOTONICS	3-0-0-0-4	Photonics deals with light generation, amplification, guiding, manipulation, and detection for harvesting information. This course introduces some of the fundamental aspects of photonics excluding generation and detection. Maxwell's Equations, Wave Equations, Dielectric Media, Constitutive Relations Electromagnetic Waves Gaussian Beams, Absorption and Dispersion Spatial and Temporal Coherence Boundary conditions, Fresnels equations and coefficients, Brewster and critical angles. **Course Reference**: 1. E. Hecht, Optics, 4th ed., Pearson Education (2001); 2. G. R. Fowles, Introduction to Modern Optics, Dover (1989); 3. Smith, F.G. & King, T.A. Optics and Photonics: An introduction, John Wiley and Sons (2007).
PSE601A	INTRODUCTION TO PHOTONICS	3-0-0-0-9	Photonics deals with light generation, amplification, guiding, manipulation, and detection for harvesting information. This course introduces some of the fundamental aspects of photonics excluding generation and detection. Maxwell Equations, Wave Equations, Dielectric Media, Constitutive Relations Electromagnetic Waves Gaussian Beams, Absorption and Dispersion Spatial and Temporal Coherence Boundary conditions, Fresnels equations and coefficients, Brewster and critical angles, **Course Reference**: 1. E. Hecht, Optics, 4th ed., Pearson Education (2001); 2. G. R. Fowles, Introduction to Modern Optics, Dover (1989); 3. Smith, F.G. & King, T.A. Optics and Photonics: An introduction, John Wiley and Sons (2007).

PSE602	PRINCIPLES OF LASERS AND DETECTORS	3-0-0-0-4	Introduction to light sources, Lasers, principle of lasing Optical cavities, longitudinal, transverse modes, Stability Interaction of radiation with matter, Spontaneous emission Absorption and stimulated emission, line broadening mechanisms Population inversion, absorption and gain coefficients Pumping schemes (Rate equation based Lasing model) Three and four level lasers CW and pulsed lasers, Q switching and modelocking. **Course Reference**: 1. Principles of Lasers, O. Svelto and D. C. Hanna,5th edition, 2010; 2. Laser Physics, Peter W. Milonni and Joseph H. Eberly, Wiley, 2nd edition, 2010; 3. Lasers, Anthony E. Siegman, University Science Books; 1st edition, 1986; 4. Laser Electronics, Joseph T. Verdeyen, Prentice Hall; 3rd edition, 1995; 5. Laser spectroscopy, W. Demtroder, 3rd edition, 2004
PSE602A	PRINCIPLES OF LASERS AND DETECTORS	3-0-0-0-9	Introduction to light sources, Lasers, principle of lasing Optical cavities, longitudinal, transverse modes, Stability Interaction of radiation with matter, Spontaneous emission Absorption and stimulated emission, line broadening mechanisms Population inversion, absorption and gain coefficients Pumping schemes (Rate equation based Lasing model) Three and four level lasers CW and pulsed lasers, Q switching and mode locking. **Course Reference: 1.** Principles of Lasers, O. Svelto and D. C. Hanna,5th edition, 2010; 2. Laser Physics, Peter W. Milonni and Joseph H. Eberly, Wiley, 2nd edition, 2010*Lasers; 3. Anthony E. Siegman, University Science Books; 1st edition, 1986; 4. Laser Electronics, Joseph T. Verdeyen, Prentice Hall; 3rd edition, 1995; 5. Laser spectroscopy, W. Demtroder, 3rd edition, 2004
PSE603	NUMERICAL METHODS IN OPTICS	3-0-0-0-4	Linear algebra: matrices, matrix inversion; QR, Singular value decomposition, systems of equations, eigen values, eigen vectors, orthonormalization, condition number Laplace and Fourier transforms Vector calculus, Cartesian tensors Ordinary differential equations, series solution, Fourier series, Special functions Iterative and direct methods for linear algebraic equations; generalized inverses, least squares Numerical differentiation and integration; Numerical solution of 1st and second order ODEs, RungeKutta method, stability, stiff systems Partial differential equations, second order equations, classification, separation of variables, **Course Reference**: 1. E. Kreyszig, Advanced Engineering mathematics, 8th edition, McGrawHill, New York,2000; 2. M.D. Greenberg, Advanced Engineering Mathematics, Prentice Hall, New Jersey, International edition, 1998; 3. I. P. Castro, An Introduction to the Digital Analysis of Stationary Signals, Taylor andFrancis, (1989).
PSE603A	NUMERICAL METHODS IN OPTICS	3-0-0-0-9	Linear algebra: matrices, matrix inversion; QR, Singular value decomposition, systems of equations, eigen values, eigenvectors, orthonormalization, condition number Laplace and Fourier transforms Vector calculus, Cartesian tensors Ordinary differential equations, series solution, Fourier series, Special functions Iterative and direct methods for linear algebraic equations; generalized inverses, least squares

			Numerical differentiation and integration; Numerical solution of 1st and second order ODEs, RungeKutta method, stability, stiff systems Partial differential equations, second order equations, classification, separation of variables, **Course Reference**: 1. E. Kreyszig, Advanced Engineering mathematics, 8th edition, McGrawHill, New York,2000; 2.M.D. Greenberg, Advanced Engineering Mathematics, Prentice Hall, New Jersey, International edition, 1998; 3. I. P. Castro, An Introduction to the Digital Analysis of Stationary Signals, Taylor and Francis, (1989).
PSE604	PHOTONICS SYSTEMS AND APPLICATIONS	3-0-0-0-4	Principles and Applications of Solidstate Laser Systems Laser diode Structures, Mechanism of photon emission in semiconductor laser, Tunable semiconductor diode laser, Rare earth doped lasers, NdGlass/NdYag/Erdoped/VdYag Lasers, Transition metal lasers, Ruby/Ti Saphire lasers, High Power Diode lasers, DPSS Lasers, Quantum cascade Laser. Principles and Applications of Liquid and Gas Laser Systems Dye laser, Tunable Lasers, Frequency stabilization, Tuning Techniques, Ar+ lasers, HeNe laser, CO2 lasers. **Course Reference**: 1. Kjell J. Gasvik, Optical Metrology, 3rd Edition, John Wiley and Sons, 2002; 2. O. Svelto and D C Hanna, Principles of lasers, 4th Ed., 1998; R W Boyd, Nonlinear optics, Academic Press, 2nd Ed, 2003; 3. M. H. Niemz, Laser Tissue Interaction Fundamentals and Applications.
PSE604A	PHOTONICS SYSTEMS AND APPLICATIONS	3-0-0-0-9	Principles and Applications of Solidstate Laser Systems Laser diode Structures, Mechanism of photon emission in semiconductor laser, Tunable semiconductor diode laser, Rare earth doped lasers, NdGlass/NdYag/Erdoped/VdYag Lasers, Transition metal lasers, Ruby/TiSaphire lasers, High Power Diode lasers, DPSS Lasers, Quantum cascade Laser. Principles and Applications of Liquid and Gas Laser Systems Dye laser, Tunable Lasers, Frequency stabilization, Tuning Techniques, Ar+ lasers, HeNe laser, CO2 lasers. **Course Reference**: 1. Kjell J. Gasvik, Optical Metrology, 3rd Edition, John Wiley and Sons, 2002; 2. O. Svelto and D C Hanna, Principles of lasers, 4th Ed., 1998; 3. R W Boyd, Nonlinear optics, Academic Press, 2nd Ed, 2003; 4. M. H. Niemz, Laser Tissue Interaction Fundamentals and Applications,
PSE605	PHOTONICS LAB TECHNIQUES	3-0-0-0-4	Electrooptic effect using LiNbO3 crystal, Acoustooptic modulator, Study of effects of loss, dispersion, amplifier noise on 10Gbps links, 40Gbps QAM modulation and coherent demodulation, Nonlinearities in fiber: Four wave mixing, Raman scattering etc. SHG generation and OPO using Nd: YAG laser OPO using BBO crystal Fresnel and Fraunhofer Diffraction HeNe laser beam parameters, Laser diode characteristics: LI characteristic, beam profile measurement, modes and spectrum using FP cavity, Michelson interferometer: setup, refractive index measurement, Nd: YAG laser characteristics, Fiber Mach Zehnder interferometer, Holography

PSE605A	PHOTONICS LAB TECHNIQUES	1-0-6-0-9	Electrooptic effect using LiNbO3 crystal Acoustooptic modulator, Study of effects of loss, dispersion, amplifier noise on 10Gbps links 40 Gbps QAM modulation and coherent demodulation, Nonlinearities in fiber: Fourwave mixing, Raman scattering etc. SHG generation and OPO using Nd: YAG laser, OPO using BBO crystal, Fresnel and Fraunhofer Diffraction, HeNe laser beam parameters, Laser diode characteristics: LI characteristic, beam profile measurement, modes and spectrum using FP cavity, Michelson interferometer: setup, refractive index measurement, Nd: YAG laser characteristics, Fiber Mach Zehnder interferometer, Holography
PSE606	RESEARCH IN PHOTONICS AND LASERS	3-0-0-0-4	Biophotonics, nanobiophotonics, Optical communication, Quantum cryptography Nonlinear optics Tomography Quantum dots, photonic crystals Laser manufacturing and materials processing Laser instrumentation, PIV, thermography, microscale imaging Satellite imaging, Clouds, aerosols, Lidar spectroscopy Multiphoton imaging.
PSE606A	RESEARCH IN PHOTONICS AND LASERS	0-0-9-0-9	Biophotonics, nanobiophotonics, Optical communication, Quantum cryptography Nonlinear optics Tomography Quantum dots, photonic crystals Laser manufacturing and materials processing Lase instrumentation, PIV, thermography, micro scale imaging Satellite imaging, Clouds, aerosols, Lidar spectroscopy Multiphoton imaging.
PSE699	M. TECH THESIS		
PSE799	PHD THESIS		
PSE899	MS - RESEARCH THESIS		

PHYSICS

PHYSICS

BS								Template No. BS-PHY-1
	SEMESTER							
	1st	2nd	3rd	4th	5th	6th	7th	8th
COURSES	MTH101A [11]	MTH102A [11]	PHY224A [12]	SO-1 [08] (PSO201A)	PHY315A [09]	PHY412A [11]	PHY461A [08]	HSS-5 (Level-2) [09]
	PHY101A [03]	PHY103A [11]	ESO-1 [~10]*	ESC201A [14]	PHY401A [11]	PHY473A [08]	PHY552A [11]	DE-3 [09]/ UGP-3 [09] (PHY557)
	PHY102A [11]	ESC101A [14]	ESO-2 [~10]*	PHY210A [06]	PHY421A [11]	PHY399A [02]	HSS-4 (Level-2) [09]	DE-4 [09]
	LIF101A [06]	CHM101A [03]	HSS-2 (Level-1) [11]	PHY226B [06]	PHY431A [11]	HSS-3 (Level-2) [09]	DE-2 [09]	OE-5 [09]
	ENG112A/HSS-1 (Level-1) [11]	CHM102A [08]	TA202A [06]	TA201A [06]	ESO-3 [~10]*	DE-1 [09]	OE-3 [09]/ UGP-2 [09] (PHY556A)	OE-6 [09]
	PE101A [03]	PE102A [03]	COM200A [05]	OE-1 [09]	-	OE-2 [09]	OE-4 [09]	UGP-4 [09] (PHY558A) (extra credits)
	TA101A [09]	-	-	-		-	UGP-1 [04] (PHY555A) (extra credits)	
	54	50	54*	49	52*	48	55	45

MINIMUM CREDIT REQUIREMENT FOR GRADUATION:

Institute Core (IC)	:	124	Credits
Department Compulsory (DC)	:	106	Credits
Department Elective (DE)	:	36	Credits
Open Elective (OE)	:	54	Credits
*SO/ ESO	:	40	Credits
HSS (Level-I)	:	22	Credits
HSS (Level-II)	:	27	Credits
Total	:	409	Credits

REMARKS:

1) *SO/ESO courses should be selected to ensure that the four courses add up to 40 credits.
2) OE credits may include 09 credits of UGP-2.
3) DE credits may include 09 credits of UGP-3.
4) UGP-1 and UGP-4 are optional and does not count towards DE/OE credits.
5) Upto 36 OE credits may be waived from the minimum requirements for students opting for either Dual Degree or Double Major programme.

DEPARTMENT OF PHYSICS			
Course ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
PHY100	INTRODUCTION TO PROFESSION	1-0-2-0-0	Frontiers of physics at various scales, unifying themes and tools ofphysics, significant discoveries, which shaped our current understanding ofthe physical World. physicsinduced technologies. The course, will include physics demonstrations along with some handson experience in the Nuclear, Laser, Low Temperature, and CondensedMatter laboratories of the Physics Department.
PHY101A	PHYSICS LABORATORY	0-0-3-0-3	Introduction to error analysis and graphdrawing; spring oscillation apparatus;trajectory of a projectile on an inclined plane; moment of inertia of a bicycle wheel; bar pendulum; torsional pendulum; coupled pendulum; study of collisionson an air track; gyroscope; current balance; measurement of capacitance using galvanometer; charging of a plate capacitor; electromagnetic induction; prism spectrometer; Fraunhofer diffraction using HeNe laser; magnetic fieldin Helmholtz coil; resonance in electrical circuits.
PHY101N	PHYSICS LAB	0-0-4-0-2	Introduction to error analysis and graphdrawing; spring oscillation apparatus;trajectory of a projectile on an

			inclined plane; moment of inertia of a bicyclewheel; bar pendulum; torsional pendulum; coupled pendulum; study of collisionson an air track; gyroscope; current balance; measurement of capacitance using galvanometer; charging of a plate capacitor; electromagnetic induction; prism spectrometer; Fraunhofer diffraction using HeNe laser; magnetic fieldin Helmholtz coil; resonance in electrical circuits.
PHY102A	PHYSICS-I	3-1-0-0-11	Transformation of Scalars and Vectors under Rotation, Form Invariance of Newtons Second Law, Forces in Nature; Solving Newtons Equations of Motion in Polar Coordinates for problems including Constraint and Friction, extension to Cylindrical and Spherical Coordinates; Potential Energy Function, Conservative and NonConservative Forces; Central Forces, Energy Equation and Diagrams, Elliptical, Parabolic, and Hyperbolic Orbits, Harmonic Oscillator with Damping, Forced Oscillations and Resonance, inclusion of Nonlinear Force and Chaotic Motion, PhaseSpace Description; NonInertial Frames of Reference, Centrifugal and Coriolis Forces, Weather Systems, Foucault Pendulum; Angular Momentum and Torque, Rigid Body Dynamics, Moment of Inertia Tensor, Principal Axes, Torque Free Precession, Gyroscopes, Eulers Equations; Special Relativity, Lorentz Transformation, Length Contraction, Time Dilation, Velocity Addition, Relativistic Dynamics, EnergyMass Relation
PHY102N	PHYSICS-I	3-1-0-1-4	Coordinate systems, elements of vector algebra in plane polar, cylindrical, spherical polar coordinate systems, dimensional analysis; solutions forone dimensional equation of motion in various forms, frames of reference, relative velocity and accelerations; Newtons laws and applications (to include friction, constraint equations, rough pulleys), line integrals, gradient, curl, conservative forces, potential, work energy theorems, energy diagrams; conservation of linear momentum and collisions, variable mass problems;central forces, gravitation, Keplers law, hyperbolic, elliptic and parabolicorbits, forced oscillations, damping, resonance; waves: motion in noninertial frames, centrifugal and Coriolis forces; conservation of angular momentum andelementary rigid body dynamics; special theory of relativity.
PHY103A	PHYSICS-II	3-1-0-0-11	Vector calculus; Electrostatic with full use of vector calculus calculation of electric fields, electrostatic potential and Laplaces equation and uniqueness of its solution; Method of images; Energy in electrostatics; Introduction to multipole expansion, Dipole moment of a charge distribution, potential and field of a dipole, force and torque on a dipole in an electric field; Electrostatics in a medium, Displacement vector and boundary conditions, linear dielectrics, force on a dielctric; Magnetostatics with full use of vector calculus, introduction to vector potential; current densities, Lorentz force law, force and torque on a magnetic dipole in a magnetic field Magnetostatics in a

			medium, magnetization, bound currents, magnetic field H, boundary condition on B and H, magnetic susceptibility, ferro, para and diamagnetism.; Faradays law, energy in magnetic field; displacement current; fields produced by time dependent electric and magnetic fields within quasistatic approximation; Maxwell's equations in vacuum and conducting and nonconducting medium, Energy in electromagnetic field, Poynting vector, plane electromagnetic waves; Reflection and refraction of electromagnetic wave from a boundary, Brewsters angle.
PHY103N	PHYSICS - II		Vector calculus; electrostatics; Gauss law and applications, electrostatic potential and curl of E; work and energy in electrostatics, Laplaces equation and first uniqueness theorem, method of images, multipoles (introduction), force and torque on dipoles; polarization, bound charges, electric displacement and boundary conditions, linear dielectrics, force on dielectrics; motion ofcharges in electric & magnetic fields; magnetostatics: current density,curl and divergence of B, Ampres law and applications, magnetization, bound currents and bound pole densities, magnetic field H, magnetic susceptibility,ferro, para and diamagnetism, boundary conditions on B and H, Faradays law, energy in magnetic field, displacement current, Maxwell's equations inmedia, Poyntings theorem, e.m. waves: wave equation, plane waves, polarization and types of polarization, energy and momentum of plane e.m. waves.propagation through linear media and conductors. reflection and transmission at normal incidence from dielectric and metal interfaces. magnetism as a relativistic phenolmenon, relativistic transformations of E and B fields (simple illustrations only), diffraction, quantum mechanics, photons, uncertainty principle, electron diffraction experiments, de Broglie hypothesis, Born interpretation, Schrdinger equation and application to 1d box problem.
PHY204	QUANTUM PHYSICS	3-1-0-1-4	Foundations of quantum mechanics Black body radiation, photoelectric effect, Compton effect, de Broglie hypothesis and its experimental verification 5 lectures Time independent and time dependent Schrodinger equation, Born interpretation,Expectation values, freeparticle wavefunctions and wave packets, uncertainty principle 5 lectures Solution of stationarystate Schrodinger equation for particle in a box, particle in a finitewell, reflection and transmission across a step potential, application to phenomena like alpha decay , one dimensional harmonic oscillator 5 lectures Solution of stationary state Schrodinger equation for the ground state of hydrogen,Discussion of excited state, Explanation of the periodic table by introduction of electron spin and Pauli's exclusion principle, StemGerlach experiment, two level systems 5 lectures Free particle wave functions and metals, Kronig Penny model and formation of bands inone dimension 4 lectures Variational principle for approximate solutions and simple applications, ground state energy of

			helium atom 3 lectures Interaction of light with matter Einstein's phenomeno logical theory, lifetime of a state,LASERS 3 lectures Feynman lectures volume III Max Jammer Conceptual development of quantum mechanics B.L. van der Waerden Sources of quantum mechanics E. Shroedinger Papers on wave mechanics R. Shankar Principles of quantum mechanics
PHY210	THERMAL PHYSICS	3-1-0-0-4	Principles of thermodynamics (with applications to simple fluids), applicationsof thermodynamics: concept of thermodynamic state, extensive and intensive variables; heat and work, internal energy function and the first lawof thermodynamics; fundamental relation and equations of state; concepts of entropy and temperature as conjugate pair of variables; secondlaw of thermodynamics, entropy maximum and energy minimum principles;thermodynamic potentials: enthalpy, Helmholtz potential, Gibbs potential;conditions of equilibrium, concepts of stable, metastable and unstable equilibrium; components and phases, GibbsDuhem relations; firstorder phase transitionsand ClausiusClapeyron equation; concepts associated with critical and multicritical phenomena, some chosen applications from surfaces and interfaces,chemical reactions (magnetic, dielectric and superconducting); heat engines and black body radiation; elementary kinetic theory of gases: equilibrium properties pressure and equation of state; transport processes momentum transport and viscosity, energy transport and thermal conductivity, chargetransport & electrical conductivity (without using Boltzmann transport equation);entropy, multiplicity and disorder: entropy measures multiplicity rather than disorder, illustration with simple examples; Maxwel'ls demon; qualitative justifications of laws of thermodynamics (without introducing ensembles), thermodynamics of irreversible processes: entropy production.
PHY210A	THERMAL PHYSICS		Principles of thermodynamics (with applications to simple fluids), applications of thermodynamics: concept of thermodynamic state, extensive and intensive variables; heat and work, internal energy function and the first law of thermodynamics; fundamental relation and equations of state; concepts of entropy and temperature as conjugate pair of variables; secondlaw of thermodynamics, entropy maximum and energy minimum principles; thermodynamic potentials: enthalpy, Helmholtz potential, Gibbs potential; conditions of equilibrium, concepts of stable, metastable and unstable equilibrium; components and phases, GibbsDuhem relations; first order phase transitionsand Clausius Clapeyron equation; concepts associated with critical and multi critical phenomena, some chosen applications from surfaces and interfaces,chemical reactions (magnetic, dielectric and superconducting); heat enginesand black body radiation; elementary kinetic theory of gases: equilibrium properties pressure and equation of state; transport processes momentum

			transport and viscosity, energy transport and thermal conductivity, charge transport & electrical conductivity (without using Boltzmann transport equation); entropy, multiplicity and disorder: entropy measures multiplicity rather than disorder, illustration with simple examples; Maxwells demon; qualitative justifications of laws of thermodynamics (without introducing ensembles),thermodynamics of irreversible processes: entropy production.
PHY218	OPTICS LAB	0-0-4-0-4	Experiments based on Fresnels equations, study of optical surfaces, Fraunhoferand Fresnel diffraction, interferometers, modulation transfer function, fibre optics, spatial filtering, characteristics of HeNe and diode lasers, etc.
PHY224	OPTICAL PHYSICS	3-1-0-0-4	Review of Maxwell's equations, wave equation and solutions for plane andspherical wavesLinear dispersion theoryDerivation and discussion of Fresnel's equations Polarization states of polarization, Jones vectors, Jones matrices, index ellipsoid Interference basics, 2beam, Nbeam discussion, interferometers Michelson and FabryPerot, multilayers for high and antireflection Diffraction Kirchhoff integral, Fraunhofer diffraction, diffraction grating coherence spatial, temporal coherence, measurement techniques, mutual coherence function, coherency matrix **Course Reference**: 1. M. Born and E. Wolf, Principles of Optics (Cambridge Univ Press); 2.J. B. Peatross and M. Ware: Physics of Light and OpticsThis book is freely available at http://optics.byu.edu/BYUOpticsBook.pdf 3.F.L.Pedrotti, L.M. Pedrotti and L.S. Pedrotti: Introduction to Optics (Pearson InternationalEdition); 4. A. Ghatak, Optics (Tata McGrawHill); 5. E.Hecht, Optics (AddisonWesley); 6. K.K. Sharma, Optics: Principles and Applications (Academic Press)
PHY224A	OPTICS	2-0-6-0-12	Review of Maxwell's equations, wave equation and solutions for plane and spherical waves Linear dispersion theory. Derivation and discussion of Fresnel's equations Polarization states of polarization, Jones vectors, Jones matrices, index ellipsoid Interference basics, 2 beam, N beam discussion, interferometers Michelson and FabryPerot, multilayers for high and antireflection Diffraction Kirchhoff integral, Fraunhofer diffraction, diffraction grating Coherence spatial, temporal coherence, measurement techniques, mutual coherence function, coherency matrix **Course Reference**: 1.M.Born and E.Wolf, Principles of Optics (Cambridge Univ Press); 2.J. B. Peatross and M. Ware: Physics of Light and OpticsThis book is freely available at http://optics.byu.edu/BYUOpticsBook.pdf; 3.F.L. Pedrotti, L.M. Pedrotti and L.S.Pedrotti: Introduction to Optics (Pearson InternationalEdition); 4.A.Ghatak, Optics (Tata McGrawHill); 5.E.Hecht, Optics (AddisonWesley); 6. K.K.Sharma, Optics: Principles and Applications (Academic Press)

PHY226B	RELATIVITY	3-1-0-0-6	Special Relativity: empirical evidence for the constancy of c, frames ofreference; 6Lorentz transformations; relativity of simultaneity; twin and otherparadoxes; Spacetime diagrams; Transformation laws for velocity, momentum, energy; mass energy equivalence; vectors; Force equations, kinematics of decays and collisions; Maxwell's equations in covariant form.
PHY301	ENERGY	3-0-0--4	Indian and global energy resources, current energy exploitation, energy demand, energy planning, renewable energy sources, wind energy, energy from water, solar energy, energy from mineral oils, nuclear energy, energy for sustainable development, environmental concerns.
PHY301A	ENERGY	3-0-0-0-9	Indian and global energy resources, current energy exploitation, energy demand, energy planning, renewable energy sources, wind energy, energy from water, solar energy, energy from mineral oils, nuclear energy, energy for sustainable development, environmental concerns.
PHY303	PRINCIPLES OF LASERS & THEIR APPLICATIONS	3-0-0--4	Gaussian optics, optical resonators and their mode structure, atomic levels, absorption, spontaneous and stimulated emission, Einstein coefficients, rate equations, population inversion, gain media, 3 and 4 level lasers CW &pulsed Lasers, Qswitching, modelocking, short pulses Ar+, CO2, Nd: YAg, diodelasers, etc.; metrology, optical communication, materials processing, holography, medical applications.
PHY303A	PRINCIPLES OF LASERS & THEIR APPLICATIONS	3-0-0-0-9	Gaussian optics, optical resonators and their mode structure, atomiclevels, absorption, spontaneous and stimulated emission, Einstein coefficients, rate equations, population inversion, gain media, 3 and 4 level lasers CW & pulsed Lasers, Qswitching, mode locking, short pulses Ar+, CO2, Nd: YAg, diodelasers, etc.; metrology, optical communication, materials processing, holography, medical applications.
PHY305	PHYSICS OF UNIVERSE	3-0-0--4	Astronomical observations and instruments, photometry, stellar spectra and structure; stellar evolution, nucleosynthesis and formation of elements, variable stars, compact stars, star clusters and binary stars, galaxies, thei revolution and origin, active galaxies and quasars, Big Bang model, early Universe and CMBR.
PHY305A	PHYSICS OF UNIVERSE	3-0-0-0-9	Astronomical observations and instruments, photometry, stellar spectra and structure; stellar evolution, nucleosynthesis and formation of elements, variable stars, compact stars, star clusters and binary stars, galaxies, thei revolution and origin, active galaxies and quasars, Big Bang model, early Universe and CMBR.
PHY306	ORDER AND CHAOS IN NATURE	3-0-0-0-4	Dynamical systems, importance of nonlinearity, nonlinear dynamics of flows (in1, 2 and 3 dimensions) and maps (in 1, 2 dimensions) in phase space (equilibrium, periodicity, bifurcation, catastrophe, deterministic chaos, strange attractor), routes to chaos (period doubling, quasiperiodicity/intermittency, universality, enormalization), measurement of chaos (Poincar section,

			Lyapunovindex, entropy), fractal geometry and fractal dimension, examples from physical sciences, engineering and biology.
PHY306A	ORDER AND CHAOS IN NATURE	3-0-0-0-9	Dynamical systems, importance of nonlinearity, nonlinear dynamics of flows (in1, 2 and 3 dimensions) and maps (in 1, 2 dimensions) in phase space (equilibrium, periodicity, bifurcation, catastrophe, deterministic chaos, strange attractor), routes to chaos (period doubling, quasiperiodicity/intermittency, universality, enormalization), measurement of chaos (Poincar section, Lyapunov index, entropy), fractal geometry and fractal dimension, examples from physical sciences, engineering and biology.
PHY307	MODERN OPTICS (ITS PHYSICS & ENGINEERING)	3-0-0--4	Review of Maxwell's and electromagnetic wave equations, wave propagation inanisotropic media, polarized light, diffraction from circular aperture and conceptof resolution, Fourier transforms and Fourier optics, spatial filtering, and image processing, coherence, holography, optical waveguides and integrated optics, optical fibres, optical communication sources (LED, lasers etc.) and detectors, and optical, electro and magneto optic effects, laser matter interaction.
PHY307A	MODERN OPTICS	3-0-0-0-9	Review of Max wells and electromagnetic wave equations, wave propagation in anisotropic media, polarized light, diffraction from circular aperture and concept of resolution, Fourier transforms and Fourier optics, spatial filtering, and image processing, coherence, holography, optical waveguides and integrated optics, optical fibers, optical communication sources (LED, lasers etc.) and detectors, and optical, electro and magneto optic effects, laser matter interaction.
PHY309A	INTRODUCTORY BIOPHYSICS		Living matter is no different from non-living matter. What makes living systems different from non-living ones are some ``processes that occur only in living systems. These dynamic processes are governed by the same laws of physics (and chemistry) that were discovered in non-living systems. The movements of biological systems are caused by real physical forces, the laws of thermodynamics impose constraints on which processes are possible, and laws of kinetics impose constraints on the rates of those processes. Therefore, understanding of life as a process cannot be complete without insight into the physics of these processes. This course is an elementary introduction to the physical principles underlying the key dynamic processes in living systems. Course Contents: strong (1) Mechano-biology of binding and bonding in living systems: Introduction to conservative, dissipative and random forces; molecular binding/unbinding events, probing non-covalent ligand receptor interactions with molecular force spectroscopy-slip bond versus catch bond. (2) Statistical thermodynamics for living systems: Concepts of conformation and structure of macromolecule of life; free

			energy change and generalized chemical force; concepts of thermodynamic equilibrium and non-equilibrium steady-state; coupled processes and engines of Life (3) Kinetics of mechano-chemical processes in living cells: Stepping of a motor protein; single molecule enzymology, fluctuating enzymatic reactions in a living cell- Michaelis-Menten form for the average rate; substrate specificity of an enzyme-induced fit versus conformational selection, kinetic proofreading for specificity amplification and role of energy dissipation; (4) Cellular and intracellular movements : Diffusion- transport in bacterial cells; transport by motor proteins in eukaryotic cells; cooperativity of motors in vesicular transport; bi-directional movements of organelles by competing motors; motor-driven export/import of polymers of life across internal membranes; movements of chromosomes during mitosis. (5) Polymers of life and template-directed polymerization: stretching and entropic spring; bending elasticity and persistence length; transcription and translation as examples of template directed polymerization, competing demands of speed and fidelity; stall, back tracking and slippage of polymerization machinery; programmed errors and recoding. (6) Entropy, information, self-organization and emergence of life: Shannon entropy and information; evolution of genetic information encoding and information processing mechanisms; essential signatures of life and its definition-debates and controversies; plausible pathways for emergence of life- roles of energy and information. **Course Reference**: 1. Physical Biology of the Cell by R. Phillips et al. (Taylor & Francis, 2009); 2. Biological Physics: Energy, Information, Life” by P. Nelson (Freeman, 2014); 3. Mechanics of the Cell; by D. Boal (Cambridge Univ. Press, 2012); 4. Biophysics: searching for principles, by W. Bialek (Princeton Univ. Press, 2012. Lecture & Venue As announced by OARS. E-mail id of instructor: debch@iitk.ac.in; Evaluation Components & Policies: End-semester Examination (weightage: 55%). Mid-semester Examination (weightage: 35%); Quizzes (combined weightage: 10%)
PHY311	PHYSICS OF NON-EQUILIBRIUM PHENOMENA	3-0-0-0-4	Introduction: examples of nonequilibrium phenomena(i) glass transition;(ii) nucleation; (iii) phase separation; experimental probes: dynamic scattering; inelastic neutron scattering, theoretical tools: two alternative theoretical approaches (a) Langevin equation dissipation, nonlinearity and noise; illustration with translational Brownian motion; (b) Fokker Planck equation diffusion and drift; illustration with (i) translational Brownian motion, (ii)rotational Brownian motion; master equation loss and gain of probabilities; concept of detailed balance metastability and bistability: Kramers theory of thermally activated barrier crossing applications in (i) chemical reactions(ii) rock magnetism. enhancing signals with the help of noise applications of stochastic resonance in (a) nonlinear optics, (b) solid state devices, (c)neuroscience, (d)

			molecular motors and biological locomotion; BeckerDoring theory of homogeneous nucleation and its modern extensions applicationsin (a) condensation and (b) crystallization. unstable states: AllenCahn scenarioof interfacial dynamics and domain growth applications to domain growth inquenched magnets; LifshitzSlyozov arguments for phase separation controlled by topological defects: application to liquid crystals; theory of coarsening of cellular patterns applications to soap froths (e.g., shaving foams); nonequilibrium steady states in driven system: drivensystems of interacting particles applications to vehicular traffic; driven surfaces applications in molecular beam epitaxy (MBE).
PHY311A	PHYSICS OF NON-EQUILIBRIUM PHENOMENA	3-0-0-0-9	Introduction: examples of nonequilibrium phenomena(i) glass transition;(ii) nucleation; (iii) phase separation; experimental probes: dynamic scattering; inelastic neutron scattering, theoretical tools: two alternative theoretical approaches (a) Langevin equation dissipation, nonlinearity andnoise; illustration with translational Brownian motion; (b) Fokker Planck equation diffusion and drift; illustration with (i) translational Brownian motion, (ii)rotational Brownian motion; master equation loss and gain of probabilities; concept of detailed balance metastability and bistability: Kramers theory of thermally activated barrier crossing applications in (i) chemical reactions(ii) rock magnetism. enhancing signals with the help of noise applications of stochastic resonance in (a) nonlinear optics, (b) solid state devices, (c)neuroscience, (d) molecular motors and biological locomotion; Becker Doring theory of homogeneous nucleation and its modern extensions applications in (a) condensation and (b) crystallization. unstable states: Allen Cahn scenario of interfacial dynamics and domain growth applications to domain growth inquenched magnets; LifshitzSlyozov arguments for phase separation controlledby topological defects: application to liquid crystals; theory of coarsening ofcellular patterns applications to soap froths (e.g., shaving foams); nonequilibrium steady states in driven system: driven systems of interacting particles applications to vehicular traffic; driven surfaces applications in molecular beam epitaxy (MBE).
PHY312	QUANTUM PROCESSES IN LOW DIMENSIONAL SEMICONDUCTORS	3----4	Characteristic length scales for quantum phenomena; scaling as a heuristic tool; scientific and technological significance of nanostructures and mesoscopic structures. brief introduction to quantum view of bulk solids, introduction tokey ideas in transport and interaction of photons with material. Quantum structures: electronic properties: science and technology realizing low dimensional structures; MBE, MOCVD, Langmuir Blodgett films, novel processes; electronic properties of hetero structures, quantum wells, quantum wires, quantum dots, and super lattices, strained layer super lattices; transport in mesoscopic structures. Resonant tunneling, hot electrons, conductance and transmission of

			nanostructures; principles of application of electronic devices. quantum structures: optical properties: optical process in low dimensional semiconductors. absorption. luminescence, excitons. application to lasers and photodetectors, transport in magnetic field: magneto transport: transport in magnetic field, semiclassical description, quantum approach, Aharonov Bohm effect, Shubnikov deHaas effect; introduction to quantum Hall effect.
PHY311A	QUANTUM PROCESSES IN LOW DIMENSIONAL SEMICONDUCTORS	3-0-0-0-9	Characteristic length scales for quantum phenomena; scaling as a heuristic tool; scientific and technological significance of nanostructures and mesoscopic structures. brief introduction to quantum view of bulk solids, introduction tokey ideas in transport and interaction of photons with material. Quantum structures: electronic properties: science and technology realizing low dimensional structures; MBE, MOCVD, Langmuir Blodget films, novel processes; electronic properties of hetero structures, quantum wells, quantum wires, quantum dots, and superlattices, strained layer super lattices; transport in mesoscopic structures. resonant tunneling, hot electrons, conductance and transmission of nanostructures; principles of application of electronic devices. quantum structures: optical properties: optical process in low dimensional semiconductors. absorption. luminescence, excitons. application to lasers and photo detectors, transport in magnetic field: magneto transport: transport in magnetic field, semiclassical description, quantum approach, Aharonov Bohm effect, Shubnikov deHaas effect; introduction to quantum Hall effect.
PHY312	NATURAL NANO MACHINES	3-0-0--4	Examples of nanomachines in living cells; differences between macroscopic and nano machines; world of nanometer and picoNewton; stochastic dynamics of nanomachines; experimental, computational and theoretical techniques; imaging and manipulating single machines; Power stroke versus Brownian ratchet mechanism; mechanochemistry of nanomachines; energetics and efficiency of nanomachines; intracellular cargo transporters; nanosize unzippers; nanosize engines for polymerization of macromolecules; exporters/importers of macromolecules; packaging machines; switches and latches; ion pumps; flagellar motor; rotary motors of ATP synthesizer; molecular sensors hair cells; nanopistons and cell crawling.
PHY311A	MODERN PHYSICS LABORATORY	1-0-4-0-4	Modern experimental techniques with a view to demonstrate the basic conceptsin physics through experiments. this course has three components: a) onelecture per week: observation, measurements, quantification and accuracies in physics, error analysis. experiments that changed classical physics: blackbody radiation, the discovery of electron, quantization of charge, e/m ratios, Millikans oil drop experiment, Stern Gerlach experiment, Rutherford scattering, Davisson Germer experiment, discovering atomic nature through optical

			spectroscopy; production and measurement of high pressure and high vacuum, low and high temperatures; femto seconds to light years. b) laboratory work (twice a week): a current list of experiments is available with the Department. c) small project/open ended experiments: These experiments will be chosenby students after brief library search in consultation with the associated faculty. These, may be carried out in research labs and using central facilities.
PHY315A	MODERN PHYSICS LABORATORY	1-0-6-0-9	Modern experimental techniques with a view to demonstrate the basic conceptsin physics through experiments. this course has three components: a) one lecture per week: observation, measurements, quantification and accuraciesin physics, error analysis. experiments that changed classical physics: blackbody radiation, the discovery of electron, quantization of charge, e/m ratios, Millikans oil drop experiment, Stern Gerlach experiment, Rutherford scattering, Davisson Germer experiment, discovering atomic nature through optical spectroscopy; production and measurement of high pressure and high vacuum, low and high temperatures; femto seconds to light years. b) laboratory work (twice a week): a current list of experiments is available with the Department. c) small project/open ended experiments: These experiments will be chosenby students after brief library search in consultation with the associated faculty. These, may be carried out in research labs and using central facilities.
PHY399A	TECHNICAL COMMUNICATION	0-0-2-2-4	TECHNICAL COMMUNICATION
PHY400	INTRODUCTION TO THE DEPARTMENT	0-0-0-0-5	The course will expose the students to research areas being pursued in the Department, and issues relevant to research as a profession. Faculty members from different sub disciplines would deliver lectures. Visits to Laboratories of the Department and relevant acilities may be arranged. Course will be zero credits; S/X grade to be given.
PHY400A	INTRODUCTION TO THE DEPARTMENT	0-0-5-0-5	The course will expose the students to research areas being pursued in the Department, and issues relevant to research as a profession. Faculty members from different sub disciplines would deliver lectures. Visits to Laboratoriesof the Department and relevant acilities may be arranged. Course will be zero credits; S/X grade to be given. 21-JUL-2014
PHY401	CLASSICAL MECHANICS	3-1-0-0-4	Review of Newtonian mcdnnics: Basicassumption; constraints, principle of virtual work, Alembert's cprinciple, generalized coordinates [3] Lagrangian mechanics: Calculu of variations, Principle of least action, Lagrange's equation, Symmetries and Noether'stheorem [8] Hamilton's equations, phase space&. phase trajectories, LiuviuUe's theorem [3]smalt oscillations, normal modes, anharmonic and nonlinear oscillators, Nonlinear dynamicsChaos (Hamiltonian systems in dissipative

			systems); strations using Duffing oscillator, double pendulum, three body problem, etc. [10]Continuum mechanics, Waves in continuous media, NavierStokes Eqn., Pressure waves [3]canonical transformations, Poisson brackets, Hamitton Jacobi theory, Actionangle variables(recommend: central force discussed here) [7]rigid body dynamics [6] **Course Reference**: 1. L. D. Landau and E. M. Lisfsitz, Mechanics, Courses of Theoretical Physics, Oxford: Pergamon, 1976; 2. H. Goldstein, C. P. Poole, and J. L. Safko, Classical Mechanics, Addison Wesley, 2001 (Indian Ed. available); 3.H. C. Corben and P. Stehle, Classical Mechanics, Dover, 1994; 4. T. W. B. Kibble, Classical Mechanics, Addison Wesley, 1994 (Indian Ed. available); 5. H. Strogatz, Nonlinear Dynamics and Chaos, Levant, 2007 (Indian Ed.)
PHY401A	CLASSICAL MECHANICS I	3-1-0-0-11	1.) Review of Newton's laws of motion, Galilean transformations, Frames of reference and pseudoforces. Symmetries in Newton's laws, Lagrangian formulation, Configuration space. Calculus of variations, Hamilton's principle of least action, Euler Lagrange's equations, Conserved quantities and Noether's theorem. Small oscillations and normal modes, An harmonic oscillators, Resonances in harmonic and an harmonic oscillaors, Parametric resonance. Secular (regular) perturbation theory, Lindtstedt-Poincare method. Rigid body dynamics. Tutorial problems: One degree of freedom (DOF) and 2) DOF simple harmonic oscillators, Double pendulum, Motion in central force field, System of particles, Charged particle in an Elecromagnetic field, Lagrangian formulation of relativistic mechanics, etc. Fixed points and linear stability analysis, Limit cycles, Flow on a torus and quasi periodicity, Qualitative discussion of Poincare-Bendixon theorem (no chaos in 2D autonomous flow). Legendre transformation, Hamiltonian formulation, Phase plane, Integral invariants, Symplectic area conservation, (Generalized) Liouville's theorem, Poincare recurrence theorem, Modified Hamilton's principle. Canonical transformations, Infinitesimal canonical transformations, Poisson brackets, Active view versus passive view of canonical transformations. Principle of varying action and Hamilton-Jacobi theory, Optico-mechanical analogy, Action-angle variables 3.) Lorenz system, Chaotic attractor, Lyapunov exponents. Qualitative discussion of non-integrability and chaos in Hamiltonian systems.N.B.: The topics in boldface* are essential for Classical Mechanics II. **Course Reference**: 1. J. V. Jose & E. J. Saletan, Classical Dynamics, Cambridge University Press (1998); 2. I. C. Percival & D. Richards, Introduction to Dynamics, Cambridge University Press (1982); 3. L. D. Landau & E. M. Lifshitz, Mechanics, Butterworth-Heinemann (1976); 4. H. Goldstein, Classical Mechanics, Addison-Wesley (1 980); 5. J. L. McCauley, Classical Mechanics, Cambridge

			University Press (1997); 6. I. M. Gelfand & S. V. Fomin, Calculus of Variations, Dover Publications (2000); 7. S. H. Strogatz, Nonlinear Dynamics and Chaos, Westview Press (2001).
PHY402A	CLASSICAL MECHANICS II	3-1-0-0-11	Review of essential basic concepts of Classical Mechanics I (PHY401), Integrable and super integrable systems, Lax pairs, Bihamiltonian systems, Toda lattice; 1.5 DoF systems: Extended phase space, Rapidly oscillating systems, Adiabatic invariance, Hannay angle, Poincare map, Homoclinic tangle, Melnikov method, Chaos in horseshoe map and symbolic dynamics; 2 DoF systems: Canonical perturbation theory, Problem of small divisors, Area-preserving maps, Poincar & eacute;-Birkhoff theorem, Introduction to KAM theory, Local vs. widespread/global chaos, Chirikov resonance-overlap criterion, Canonical perturbation theory, Problem of small divisors, Area-preserving maps, Poincaré-Birkhoff theorem, Introduction to KAM theory, Local vs. widespread/global chaos, Chirikov resonance-overlap criterion; 2 DoF systems: Geometry of resonances, Overview (no proofs) of Nekhoroshev theorem and Arnold diffusion, Fermi; Ulam-Tsingou problem, Kuramoto model and synchronization; Continuous systems: Lagrangian and Hamiltonian formulations. Recommended **Course Reference** : 1. J. V. Jose & E. J. Saletan, Classical Dynamics, Cambridge University Press (1998); 2. H. Goldstein, C. Poole, & J. Safko, Classical Mechanics, Addison-Wesley (2001); 3. A. Lichtenberg & M. Lieberman, Regular and Chaotic Dynamics, Springer (1992); 4. M. Tabor, Chaos and Integrability in Nonlinear Dynamics, Wiley-Interscience (1974); 5. S. Wiggins, Introduction to Applied Nonlinear Dynamical Systems and Chaos, Springer (2003); 6. A. Goriely, Integrability and Nonintegrability of Dynamical Systems, World Scientific (2001).
PHY407	SPECIAL & GENERAL RELATIVITY	3-0-0--4	Special Relativity: empirical evidence for the constancy of c, frames of reference;Lorentz transformations; relativity of simultaneity; twin and other paradoxes,transformation laws for velocity, momentum, energy; massenergy equivalence;force equations, kinematics of decays and collisions, Maxwells equationsin covariant form, representations of the Lorentz group and SL(2,C).Introduction to General Relativity: principle of equivalence; Machs principle,Riemannian geometry; Christoffel symbols, the curvature and stress energy tensors; the gravitational field equations; geodesics and particle trajectories, Schwarzchild solution; experimental tests, basic cosmology, FRW metric; cosmological expansion; cosmic microwave background; helium abundance; anisotropies in the CMBR.
PHY407A	SPECIAL & GENERAL RELATIVITY	3-0-0-0-9	Special Relativity: empirical evidence for the constancy of c, frames of reference;Lorentz transformations; relativity of simultaneity; twin and other paradoxes,transformation laws for velocity, momentum, energy; massenergy

			equivalence;force equations, kinematics of decays and collisions, Maxwells equationsin covariant form, representations of the Lorentz group and SL(2,C).Introduction to General Relativity: principle of equivalence; Machs principle,Riemannian geometry; Christoffel symbols, the curvature and stressenergytensors; the gravitational field equations; geodesics and particle trajectories, Schwarzchild solution; experimental tests, basic cosmology, FRW metric; cosmological expansion; cosmic microwave background; helium abundance; anisotropies in the CMBR.
PHY412	STATISTICAL MECHANICS	3-1-0-0-4	1. Review of Thermodynamics, Probability theory, Random Walk, Brownianmotion, Diffusion Equation, idea of Langevin and Fokker Planck Equations; 2. Basic principles of Equilibrium Classical Statistical Mechanics, MicroCanonical, Canonical and Grand Canonical ensembles; 3. Quantum Statistical Mechanics, Density Matrix, Ideal Quantum Gases andtheir properties, BoseEinstein Condensation, Free Electron gas; 4 a)Ising model of Magnetism, Transfer Matrix method, Mean field theory b) Phase Transitions, CurieWeiss theory, Landau theory, Scaling near acritical point. **Course Reference**: 1. Reif, Huang, Pathria, Landau and Lifshitz, S. K. Ma, Chaudhury and Stauffer; 2. A.C. Melissiuos and J. Napolitano, Experiments in Modern Physics, znct ed. (Academic Press, Amsterdem, 2003); 3. Resource Files on Experiments maintained in the Laboratory; 4. P. R. Beviugton, Data Reduction and Error Analysis for Physical Sciences (McGraw Hill, 1969).
PHY412A	STATISTICAL MECHANICS	3-1-0-0-11	1. Review of Thermodynamics, Probability theory, Random Walk, Brownianmotion, Diffusion Equation, idea of Langevin and FokkerPlanck Equations [8]2. Basic principles of Equilibrium Classical Statistical Mechanics, MicroCanonical, Canonical and Grand Canonical ensembles. [10]3. Quantum Statistical Mechanics, Density Matrix, Ideal Quantum Gases andtheir properties, BoseEinstein Condensation, Free Electron gas [10]4 aliasing model of Magnetism, Transfer Matrix method, Mean field theory [4]b) Phase Transitions, CurieWeiss theory, Landau theory, Scaling near acritical point. [8] **Course Reference**: 1. Reif, Huang, Pathria, Landau and Lifshitz, S. K. Ma, Chaudhury and Stauffer; 2. A.C. Melissiuos and J. Napolitano, Experiments in Modern Physics, znct ed. (Academic Press, Amsterdem, 2003); 3. Resource Files on Experiments maintained in the Laboratory; 4. P. R. Beviugton, Data Reduction and Error Analysis for Physical Sciences (McGraw Hill, 1969).
PHY421	MATHEMATICAL METHODS I	3-1-0-0-4	Vector analysis; curvilinear coordinates; matrices and vector spaces, tensors, function spaces; Hilbert spaces; orthogonal expansions; operators ininfinite dimensional spaces, Fourier series and Fourier transform, generalized functions; Dirac delta function, groups and their representations; discrete groups, Lie groups and Lie algebras, applications.

PHY421A	MATHEMATICAL METHODS I	3-1-0-0-11	Vector analysis; curvilinear coordinates; matrices and vector spaces, tensors, function spaces; Hilbert spaces; orthogonal expansions; operators ininfinite dimensional spaces, Fourier series and Fourier transform, generalized functions; Dirac delta function, groups and their representations; discrete groups, Lie groups and Lie algebras, applications.
PHY422	MATHEMATICAL METHODS II	3-1-0-0-4	Functions of a complex variable, ordinary differential equations, special functions, differential operations and SturmLiouville theory, partial differential equations, Greens functions.
PHY422A	MATHEMATICAL METHODS II	3-1-0-0-11	Functions of a complex variable, ordinary differential equations, special functions, differential operations and SturmLiouville theory, partial differential equations, Greens functions.
PHY431	QUANTUM MECHANICS I	3-1-0-0-4	Origins of Quantum Theory, Schroedinger Equation, Applicationto OneDimensional Problems, WKB Approximation, Central Potentials, Quantum Harmonic Oscillator, Hydrogen Atom, Hilbert Space Formalism for Quantum Mechanics, Synunetries inQuantum Mechanics, Angular Momentum, Addition of Angular Momenta, Identical Particles, Spin and Statistics, Pauli Exclusion Principle, Variational Method, Applications to Helium Atomand Hydrogen Molecule Ion.
PHY431A	QUANTUM MECHANICS I	3-1-0-0-11	Origins of Quantum Theory, Schroedinger Equation, Applicationto One Dimensional Problems, WKB Approximation, Central Potentials, Quantum Harmonic Oscillator, Hydrogen Atom, Hilbert Space Formalism for Quantum Mechanics, Synunetries inQuantum Mechanics, Angular Momentum, Addition of Angular Momenta, Identical Particles, Spin and Statistics, Pauli Exclusion Principle, Variational Method, Applications to Helium Atomand Hydrogen Molecule Ion.
PHY432	QUANTUM MECHANICS II	3-1-0-0-4	Bound State Perturbation Theory, TimeDependent PerturbationTheory, Semiclassical Treatment of Radiation, Scattering Theory, Relativistic Wave Equations, Foundational Issues in Quantum Mechanics, Quantum Computation. (1) Powell and Crasemaun (2) Feymnan Lectures vol. III (3) Merzbacher (4) Gasiorowicz (5) Schiff (6) Sakurai (7) LandauLifshitz (8) CohenTaunoudji (9) Griffiths
PHY432A	QUANTUM MECHANICS II	3-1-0-0-11	Bound State Perturbation Theory, Time Dependent PerturbationTheory, Semiclassical Treatment of Radiation, Scattering Theory, Relativistic Wave Equations, Foundational Issues in Quantum Mechanics, Quantum Computation. (1) Powell and Crasemaun (2) Feymnan Lectures vol. III (3) Merzbacher (4) Gasiorowicz (5) Schiff (6) Sakurai (7) LandauLifshitz (8) CohenTaunoudji (9) Griffiths
PHY441	ELECTRONICS	2-1-4--5	Review of network theorems and network analysis Operation Amplifier and negative feedback OpAmp limitations and applications Circuits with OpAmps and

			diodes Interfacing BJT with OpAmps MOSFETs Digital electronics: Gates, flipflops, counters, timers Microcontroller: basics and architecture Assembly language programming with microcontroller applications; **Course Reference**: 1. The art of electronics; by P. Horowitz and W. Hill; Student Manual for The Art of Electronics; by T. C. Hayes and P. Horowitz; 2. OpAmps and linear integrated circuits; by R.A. Gayakwad; 3. Digital fundamentals; by T. L. Floyd; 4. Digital computer electronics; by A.P. Malvino and J.A. Brown; 5. The 8051 Microcontroller: architecture, programming and applications; by K. J. Ayala
PHY441A	ELECTRONICS	2-1-3--11	Review of network theorems and network analysis Operation Amplifier and negative feedback OpAmp limitations and applications Circuits with OpAmps and diodes Interfacing BJT with OpAmps MOSFETs Digital electronics: Gates, flipflops, counters, timers Microcontroller: basics and architecture Assembly language programming with microcontroller applications; **Course Reference**: 1. The art of electronics; by P. Horowitz and W. Hill; Student Manual for The Art of Electronics; by T. C. Hayes and P. Horowitz; 2. OpAmps and linear integrated circuits; by R.A. Gayakwad; 3. Digital fundamentals; by T. L. Floyd; 4. Digital computer electronics; by A.P. Malvino and J.A. Brown; 5. The 8051 Microcontroller: architecture, programming and applications; by K. J. Ayala
PHY461	EXPERIMENTAL PHYSICS I	0-0-8-0-4	Experiments in General Physics, Optics, Nuclear Physics and Condensed MatterPhysics (List of current experiments available with the Physics Department in the form of a manual).
PHY461A	EXPERIMENTAL PHYSICS I	0-0-8-0-8	Experiments in General Physics, Optics, Nuclear Physics and Condensed MatterPhysics (List of current experiments available with the Physics Department in the form of a manual).
PHY462	EXPERIMENTAL PHYSICS II	0-0-8-0-4	Experiments in General Physics, Optics, Nuclear Physics and Condensed Matter Physics (List of current experiments available with the Department in the formof a manual).
PHY462A	EXPERIMENTAL PHYSICS II	0-0-8-0-8	Experiments in General Physics, Optics, Nuclear Physics and Condensed Matter Physics (List of current experiments available with the Department in the form of a manual).
PHY473	COMPUTATIONAL PHYSICS	2-1-0-3-5	Introduction to computers, FORTRAN/C; finite difference calculus, interpolation and extrapolation, roots of equations, solution of simultaneous linear algebraicequation, least squares curve fitting, numerical integration, numerical solutionof ordinary differential equations, matrix eigenvalue problems.
PHY473A	COMPUTATIONAL PHYSICS	2-0-2-0-8	Introduction to computers, FORTRAN/C; finite difference calculus, interpolationand extrapolation, roots of equations, solution of simultaneous linear algebraic

			equation, least squares curve fitting, numerical integration, numerical solution of ordinary differential equations, matrix eigenvalue problems.
PHY500	M SC REVIEW PROJECT I	0-0-8-0-4	M.Sc. Review Project I
PHY501	M SC REVIEW PROJECT II	0-0-9--4	M.Sc. Review Project II
PHY501A	M SC REVIEW PROJECT II	0-0-9--9	M.Sc. Review Project II
PHY502	M.SC. REVIEW PROJECT III	0-0-8-0-4	M.Sc. Review Project III
PHY502A	M.SC. REVIEW PROJECT III	0-0-8-0-8	M.Sc. Review Project III
PHY502N	M SC EXPERIMENTAL PROJECT III	3-0-0-0-4	Student must carry out review of an advanced topic of current interest andmake a presentation to an Evaluation Committee. Letter Grades will be awarded.PHY 500: M.Sc. Review Project IPHY 501: M.Sc. Review Project II, PHY 502: M.Sc. Review Project III: These projects will involve literature survey and collection of material, Detailed study of the material, verification of results and writing of the review. Review Projects will include exposure to and conduct of Experiments as required.
PHY524	INTRODUCTION TO ATOMIC AND NUCLEAR PHYSICS	3-1-0-0-4	Atomic Physics: Review of atomic structure of H, atomic structureof two electron system, alkali system, HartreeFock method, LS coupling,molecular binding, LCAO, LCMO; molecular spectra (electronic, rotational,vibrational etc.), Raman effect, modern experimental tools of spectroscopy.Nuclear Physics: General properties of nuclei, nuclear two body problem, nuclear force and nuclear models, nuclear decay, nuclear reaction kinematicsand classification of nuclear reactions (compound nuclear, direct etc),heavy ion reactions, nuclear fission and fusion, brief overview of ion beam applications for materials and solid state studies, modern experimental tools of pure and applied nuclear physics.
PHY524A	INTRODUCTION TO ATOMIC AND NUCLEAR PHYSICS	3-1-0-0-11	Atomic Physics: Review of atomic structure of H, atomic structure of two electron system, alkali system, HartreeFock method, LS coupling, molecular binding, LCAO, LCMO; molecular spectra (electronic, rotational, vibrational etc.), Raman effect, modern experimental tools of spectroscopy. Nuclear Physics: General properties of nuclei, nuclear two body problem, nuclearforce and nuclear models, nuclear decay, nuclear reaction kinematics and classification of nuclear reactions (compound nuclear, direct etc),heavy ion reactions, nuclear fission and fusion, brief overview of ion be amapplications for materials and solid state studies, modern experimental tools of pure and applied nuclear physics.
PHY526A	NUCLEAR AND PARTICLE PHYSICS	3-1-0-0-11	Nuclear Physics: General properties of nuclear two body problem, Nuclear force and nuclear models, Nuclear decay, Nuclear reaction kinematics, Scattering and

			reaction cross section, Optical Model, Classification of nuclear reactions (compound nuclear, direct etc.), BreitWigner resonance formula, Nuclear fission and fusion. Particle Physics: Natural Units, Evidence for four fundamental interactions, Leptons and hadrons, Historical introduction to the particle zoo, introduction to cross sections and decay rates, Particle accelerators and detectors, invariance principles and conservation laws of parity, Charge conjugation, Time reversal and CP, isospin, Strangeness. **Course Reference**: 1. Kaplan, Nuclear Physics (Narosa); 2. S. Krane, Introduction to Nuclear Physics (Wiley); 3. D.H. Perkins, Introduction to High Energy Physics (Cambridge University Press).
PHY543	CONDENSED MATTER PHYSICS I	3-1-0--4	Free electron theory; heat capacity; transport properties; Hall effect; elementary concepts of quantum Hall effect, quantization of conductance in a metallic nanowire Structure and scattering; crystalline solids, liquids and liquid crystals; nanostructures; buckyballs, Energy band theory; Bloch's theorem; nearly free electron model; tight binding model; application to graphene and nanotubes, semiclassical dynamics; notion of an electron in a DC electric field; effective mass, holes, crystal binding; types of solids; van der Waals solids, ionic and covalent solids, metals, Phonons and heat capacity; lattice vibrations; adiabatic & harmonic approximations, vibrations of mono and diatomic lattices, lattice heat capacity, Einstein and Debye models Semiconductors; intrinsic & extrinsic semiconductors, laws of mass action, electron & holemobilities. Impurity levels, pnjunctions Superconductivity: experimental survey, Meissner effect, London's equation, BCS theory, Ginzburg Landau theory, flux quantization, Magnetism: exchange interaction, diamagnetism, paramagnetism, ferromagnetism & antiferromagnetism, Hund's rules, Pauli paramagnetism, Heisenberg model, mean field theory, spin waves, RK.KY interaction, giant and colossal magneto resistance. **Course Reference**: 1. Introduction to Solid State Physics by C. Kittel; 2. Solid State Physics by N. W. Ashcroft and N. D. Mermin; 3. Solid State Physics by H Ibach and Hans Luth.
PHY543A	CONDENSED MATTER PHYSICS I	3-1-0-0-11	Free electron theory; heat capacity; transport properties; Hall effect; elementary concepts of quantum Hall effect, quantization of conductance in a metallic nanowire Structure and scattering; crystalline solids, liquids and liquid crystals; nano structures; bucky balls, Energy band theory; Bloch's theorem; nearly free electron model; tight binding model; application to graphene and nanotubes, semiclassical dynamics; notion of an electron in a DC electric field; effective mass, holes, crystal binding; types of solids; van der Waals solids,ionic and covalent solids, metals,Phonons and heat capacity; lattice vibrations; adiabatic & harmonic approximations, vibrations of mono and diatomic lattices, lattice heatcapacity, Einstein and

			Debye models Semiconductors; intrinsic & extrinsic semiconductors, laws of mass action, electron & hole mobilities. Impurity levels, pnjunctions Superconductivity: experimental survey, Meissner effect, London's equation, BCS theory, Ginzburg Landau theory, flux quantization, Magnetism: exchange interaction, diamagnetism, paramagnetism, ferromagnetism & anti ferromagnetism, Hund's rules, Pauli paramagnetism, Heisenberg model, mean field theory, spin waves, RK.KY interaction, giant and colossal magneto resistance. **Course Reference**: 1. Introduction to Solid State Physics by C. Kittel; 2. Solid State Physics by N. W. Ashcroft and N. D. Mermin; 3. Solid State Physics by H Ibach and Hans Luth
PHY552	CLASSICAL ELECTRODYNAMIC S I	3-1-0-0-4	Electrostatics Laplace and Poisson equatlons; ciil.d, their solutions. CToil.S, Uniqueness theorem, multipole expansion (11 lectures) Magnetostatics (12 lectures) Boundaryvalue problems involving dielectrics and magnetic materials(6 lectures) Maxwell's equations, electromagnetic waves in medium, Poyntings; theorem, momentum and angular momentum of electromagnetic fields (10 lectures) Electromagnetic radiation, retarded potentials, Lorentz and Coulomb gaugeI(11 lectures)relativistic transformation of electric and magnetic fields (45lectures) Classical Electrodynamics, John D. Jackson
PHY552A	CLASSICAL ELECTRODYNAMIC S I	3-1-0-0-11	Electrostatics Laplace and; Poisson equations; ciil.d ;their SOh.f.;CToil.S,Uniqueness theorem, multipole expansion (11 lectures) Magnetostatics (12 lectures) Boundary value problems involving dielectrics and magnetic materials(56 lectures) Maxwells equations, electromagnetic waves in medium, Poyntings theorem, momentum and angular momentum of electromagnetic fields (10 lectures) Electromagnetic radiation, retarded potentials, Lorentz and Coulomb gaugeI 11 lectures) relativistic transformation of electric and magnetic fields (5 lectures) Classical Electrodynamics, John D. Jackson
PHY553	CLASSICAL ELECTRODYNAMIC S II	3-1-0--4	Special relativity, Minkowski space and four vectors, concept of four velocity, four acceleration and higher rank tensors, relativistic formulation of electrodynamics, Maxwell equations in covariant form, gauge invariance and four potential, the action principle and electromagnetic energy momentum tensor. Linard Weichert potentials, radiation from an accelerated charge, Larmor formula, brems strahlung and synchrotron radiation, multipole radiation, dispersion theory, radiative reaction, radiative damping, scattering by free charges; applications to waveguides, fibres and plasmas.
PHY553A	CLASSICAL ELECTRODYNAMIC S II	3-1-0-0-11	Special relativity, Minkowski space and four vectors, concept of four velocity, four acceleration and higher rank tensors, relativistic formulation of electrodynamics, Maxwell's equations in covariant form, gauge invariance and four potential, the action principle and electromagnetic energy momentum tensor. LinardWeichert potentials,

			radiation from an accelerated charge, Larmor formula, brems strahlung and synchrotron radiation, multipole radiation, dispersion theory, radiative reaction, radiative damping, scattering by free charges; applications to waveguides, fibres and plasmas.
PHY553B	CLASSICAL ELECTRODYNAMIC S II	3-0-0--4	Special relativity, Minkowski space and four vectors, concept of four velocity, four acceleration and higher rank tensors, relativistic formulation of electrodynamics, Maxwell’s equations in covariant form, gauge invariance and four potential, the action principle and electromagnetic energy momentum tensor. Linard Weichert potentials, radiation from an accelerated charge, Larmor formula, brems strahlung and synchrotron radiation, multipole radiation, dispersion theory, radiative reaction, radiative damping, scattering by free charges; applications to waveguides, fibres and plasmas.
PHY555A	BACHLOR OF SCIENCE PROJECT -1	0-0-4-0-4	BACHELOR OF SCIENCE PROJECT I
PHY556A	BACHLOR OF SCIENCE PROJECT -II	0-0-0-9-9	BACHELOR OF SCIENCE PROJECT II
PHY563	M.SC. PROJECT I	0-0-11-0-4	Experimental project in a research laboratory: 1. Literature survey and preparation for the project.
PHY563A	M.SC. PROJECT I	0-0-11-0-11	Experimental project in a research laboratory: 1. Literature survey and preparation for the project.
PHY565	M.SC. PROJECT II	0-0-11-0-4	Experimental project in a research laboratory: 2. Development and testing of experimental setup.
PHY565A	M.SC. PROJECT II	0-0-11--11	Experimental project in a research laboratory: 2. Development and testing of experimental setup.
PHY566	M.SC. PROJECT III	0-0-8-0-4	Experimental project in a research laboratory: 3. Data acquisition and analysis.
PHY568	M.SC. PROJECT IV	0-0-8-0-4	Experimental project in a research laboratory: 4. Preparation of report and interpretation of results.
PHY570	THEORETICAL PROJECT I	-0-8--4	Study of a research - oriented topic in Theoretical Physics with an aim to bring the student in contact with a concrete research area of current interest. Solvinga small problem in this area is required, detailing the explicit statement of the problem, relevance and context, steps involved, tools employed, proposed work plan, and results obtained.
PHY571	THEORETICAL PROJECT II	0-0-8-0-4	Advanced research oriented theoretical study in continuation of project work undertaken in PHY 570, or study of another research-oriented topic in Theoretical Physics with an aim to bring the student in contact with a concrete research area of current interest. Solving a small problem in the area is required, detailing the explicit statement of the problem, relevance and context, steps involved, tools employed, proposed work plan and results obtained.
PHY590	SPECIAL TOPICS IN PHYSICS	0-0-8--4	Details of contents will be announced when the course is offered. If the number of students is less than 5, this may

			be floated as a Reading Course for studentswith CPI 8.0 or above.
PHY590A	SPECIAL TOPICS IN PHYSICS	0-0-9-0-9	Details of contents will be announced when the course is offered. It the numbers of students is less than 5, this may be floated as a Reading Course for students with CPI 8.0 or above.
PHY599	M.SC.RESEARCH PROJECT II	0-0-24-0-12	M. Sc. Project I
PHY599A	M.SC.RESEARCH PROJECT II	0-0-27-0-27	M. Sc. Project II
PHY600	INTRODUCTION TO HIGH PERFORMANCE COMPUTING FOR SCIENTISTS AND ENGINEERS	3-0-0-0-5	1. Introduction to HPC and scientific computing. Overview of major applications. 2. Supercomputing architecture; multicores; shared memory; switch etc. 3. Review of basics of C/Fortran programming. 4. Programming in Message Passing Interface (MPI). 5. Programming in Open MP. 6. Case study on one major application. **Course Reference**: 1. P.S. Pacheco, An Introduction to Parallel Programming, Elsevier (2011); 2. M. Quinn, Parallel Programming in C and OpenMP, McGraw Hill Education (India) (2003); 3. A. Grama, A. Gupta, G. Karypis, and V. Kumar, Introduction to Parallel Computing, Pearson (220). 24-MAR-15
PHY601	REVIEW OF CLASSICAL MACHANICS	1-3-0--4	Problem oriented review of Classical Mechanics, Newtons laws ofmotion, Galilean transformations, Particle mechanics, System ofparticles, Noninertial frames, Pseudoforces. Small oscillations and normal modes. Lagrangian formulation, Configuration space, Hamiltons principle of least action, Symmetries and conservation laws, Rigid bodymotion, Hamiltonian formulation. Phase space, Liouvilles theorem, Canonical transformations, Poisson brackets, HamiltonJacobi theory, Actionangle variables. Integrability, Perturbation theory, Time dependent Hamiltonian, Introduction to chaos, Chaotic attractor (and repeller), Lyapunov exponent, Special relativity. **Course Reference** : 1. J. V. Jose & E. J. Saletan, Classical Dynamics, Cambridge University Press (1998); 2. I. C. Percival & D. Richards, Introduction to Dynamics, Cambridge University Press(1982); 3. L. D. Landau & E. M. Lifshitz, Mechanics, ButterworthHeinemann (1976); 4. H. Goldstein, Classical Mechanics, Addison Wesley (1980); 5. S. H. Strogatz, Nonlinear Dynamics and Chaos, Westview Press (2001); 6. M. Tabor, Chaos and Integrability in Nonlinear Dynamics, Wiley Interscience (1974).
PHY601A	REVIEW OF CLASSICAL MACHANICS	1-3-0--9	Problem oriented review of Classical Mechanics, Newtons laws ofmotion, Galilean transformations, Particle mechanics, System of particles, Noninertial frames, Pseudo forces. Small oscillations and normal modes. Lagrangian formulation, Configuration space, Hamiltons principle of least action, Symmetries and conservation laws, Rigid bodymotion, Hamiltonian formulation. Phase space, Liouvilles theorem, Canonical transformations,

			Poisson brackets, Hamilton Jacobi theory, Actionangle variables. Integrability, Perturbation theory, Time dependent Hamiltonian, Introduction to chaos, Chaotic attractor (and repeller), Lyapunov exponent, Special relativity. **Course Reference** : 1. J. V. Jose & E. J. Saletan, Classical Dynamics, Cambridge University Press (1998); 2. I. C. Percival & D. Richards, Introduction to Dynamics, Cambridge University Press(1982); 3. L. D. Landau & E. M. Lifshitz, Mechanics, Butterworth Heinemann (1976); 4. H. Goldstein, Classical Mechanics, AddisonWesley (1980); 5. S. H. Strogatz, Nonlinear Dynamics and Chaos, Westview Press (2001); 6. M. Tabor, Chaos and Integrability in Nonlinear Dynamics, Wiley Interscience (1974).
PHY602	REVIEW OF QUANTUM PHYSICS I	1-3-0--4	Problemoriented review of basic quantum mechanics: Schrdinger equation, simple potential problems, quantum dynamics, angular momentum, perturbation theory, scattering, applications to atoms and molecules.
PHY602A	REVIEW OF QUANTUM MECHANICS	1-3-0-0-9	Problem oriented review of Quantum Mechanics. Historical development of quantum mechanics, wave packets, Schrodinger; sequation, twolevel systems. Solution (analytical and numerical) of time independent Schrodinger equation for various physically relevant potentials; angular momentum algebra, spherical harmonics. Numerical solution of the radial Schrodinger equation for arbitrary spherically symmetric potential. Equivalence of Heisen berg approach and Schrodinger approach; matrix mechanics. Quantization of electromagnetic field in a cavityand in free space. Approximation methods: perturbation theory andvariation principle for time independent problems, WKB approximation. Time dependent Schrodinger equation. Timedependent perturbation theory and matter radiation interaction. Selection rules for dipole radiation. Adiabatic and sudden approximations. Topics in (i) scattering theory, (ii) relativistic quantum mechanics, (ii) introduction to path integral formulation, (iv) identical particles. Problems of current interest, many body physics. **Course Reference**: 1. J. J. Sakurai, Modern Quantum Mechanics; 2. L.I. Schiff, Quantum Mechanics; 3. E. Merzbacher, Quantum Mechanics; 4. R. Shankar, Principles of Quantum Mechanics; 5. Loudon, Quantum theory of light.
PHY603	REVIEW OF CLASSICAL PHYSICS II	1-3-0--4	Problem oriented review of electromagnetism, optics and thermodynamics: electric fields, potentials, Gausss law, dielectrics, magnetic fields, Ampreslaw, Faradays law, Maxwell's equations, electromagnetic waves, interference, diffraction, polarization.
PHY603A	REVIEW OF CLASSICAL ELECTRODYNAMICS	1-3-0-0-9	Problem oriented review of Classical Electrodynamics. Electrostatics and Magnetostatics: Methods of solving electrostatic problems in cartesian, spherical and cylindricalcoordinates, Green's function and Boundary

			value problems, both analytical and numerical solutions. Multipole expansion, Macroscopic media, Dielectrics and Magnetic media. Electrodynamics: Faraday's law, Displacement current, Poynting Vector, Conservation laws. Electromagnetic waves in free space and different media, waveguides. Radiation: Retarded potential, electric and magnetic dipole fields, linear antenna. Special Relativity: Transformation of electromagnetic fields. Scattering and diffraction, Resonant cavities, Optical fibers, Dispersion. **Course Reference**: 1. J. D. Jackson, Classical Electrodynamics; 2. Landau and Lifshitz, Electrodynamics of continuous media; 3. Griffiths, Electrodynamics; 4. Zangwill, Electrdynamics; 5. Reitz, Christy and Millford, Electrodynamics.
PHY604	REVIEW OF QUANTUM PHYSICS II	1-3-0--4	Problem oriented survey of statistical mechanics, deuteron problem, nuclear scattering, alpha and beta decay, elementary particle phenomenology, crystalstructure, symmetry, periodic potential, bands, metals and semiconductors.
PHY604A	REVIEW OF STATISTICAL MECHANICS	1-3-0-0-9	Problem oriented review of Statistical Mechanics. Review of thermodynamics: Laws of thermodynamics; thermodynamics of phase transitions and phase diagram. Review of Ensembles and rules of calculation: Microcanonical, canonical, grand canonical and other ensembles; applications tomodels of ideal classical and quantum gases. Models of classical interacting systems: Ising model in 1 dimension: exact solution by transfer matrix; Peierls Griffiths argument for Ising model in 2 dimensions; Mean field approximation for magnets and fluids, Landau Theory, critical exponents, upper and lower critical dimensions. Models of quantum interacting systems: Density matrix, Transverse Ising model, exact solution by Jordan Wigner transformation, Heisenberg model magnons; Mermin Wagner theorem; general theory of quantum phase transitions. Brief overview of Nonequilibrium statistical mechanics: Random walk and diffusion, Markov processes and master equation; Systems near equilibrium Linear Response Theory, Fluctuation Dissipation Theorem; Escape over a barrier relaxation-phenomena; critical dynamics. Supplementary reading materials for term papers: Momentum Space Renormalization Group, Realspace Renormalization Group, Duality in Statistical mechanics, Various types of series expansions, Boltzmann equation, Molecular hydrodynamics, BBGKY hierarchy; Random and glassy systems, Linear and branched Polymers, Percolation; XY model and vortices super fluidity. **Course Reference**: 1. M. Kardar;Statistical Physics of Particles (CUP, 2007); 2. R.K. Pathria; Statistical Mechanics; (Academic Press, 2007); 3. D. Chowdhury and D. Stauffer; Principles of Equilibrium Statistical Mechanics(Wiley, 2000); 4. B.K. Chakrabarti et al. Quantum Phase Transitions in Transverse Ising Models

			;(Springer, 1996); 5. S.K. Ma, Statistical Mechanics (World Scientific, 1985); 6. L.D. Landau and E.M. Lifshitz;Statistical Mechanics; (Academic Press, 1975); 7. K. Huang; Statistical Mechanics; (Wiley, 1987).
PHY605	REVIEW OF MATHEMATICAL METHODS IN PHYSICS	1-3-0-0-4	Problem oriented review of Mathematical Methods in Physics.Vector spaces Discrete and continuous: orthogonality, operator algebra. Hermitian and unitary operators, projection operators, matrices and applications in Physics. Calculus of variations, function spaces and Hilbert spaces, Orthogonal polynomials, expansions in orthogonal polynomials, generating functions. Integral transforms (e.g Fourier, Laplace, etc.) and applications to physics. Differential equations: General introduction to ordinary differential equations, linear first and second order ordinary differential equations, singular points, series solutions Frobenius method, second solution, inhomogeneous equations Green's function, SturmLiouville theory, partial differential equations, characteristics, Boundary conditions. Special functions and applications in Physics. Complex analysis: Cauchy Riemann conditions, Cauchy Goursat theorem, Cauchy integral formula, Contour integrals, Taylor andLaurent Series, The residue theorem. Applications of complex analysis to physics problems. **Course Reference**: 1. Sadri Hassani, Mathematical Physics: a modern introduction to its foundations (Springer); 2. Arfken, Weber Mathematical Methods for Physicists (Academic Press); 3. Tulsi Dass and S. K. Sharma, Mathematical methods in Classicaland Quantum Physics (University Press); 4. A. K. Kapoor, Complex variables (World Scientific); 5. Mathews, Walker Mathematical Methods of Physics (AddisonWesley); 6. Schaum Series Vector Analysis 7. A. W. Joshi, Matrices and Tensors in Physics (New age international)
PHY611	ADVANCED QUANTUM MECHANICS	3-0-0--4	Second quantization; interaction picture; Smatrix; diagrammatic methods; many particle Greens functions; basic techniques in manybody physics; additional topics (at the discretion of the Instructor).
PHY612	INTRODUCTION GROUP THEORY & ITS APPLICATION TO QUANTUM MECH.	3-0-0--4	Elements of finite groups. representation theory. applications to physical systems: crystal symmetries. continuous groups. Lie algebras and their elementary applications. global properties of groups.
PHY613	ADVANCED STATISTICAL MECHANICS	3-0-0--4	Equilibrium statistical mechanics, phase transitions, critical phenomena, superfluidity, super conductivity, nonequilibrium statistical mechanics, Langvin equations, FokkerPlanck equations, ergodic hypothesis and the basic postulate.
PHY613A	ADVANCED STATISTICAL MECHANICS	3-0-0-0-9	Equilibrium statistical mechanics, phase transitions, critical phenomena, superfluidity, supercondictivity, non-equilibrium statistical mechanics, Langevin equations, Fokker Planck equations, ergodic hypothesis and the basic postulate.

PHY614	SPECIAL TOPICS IN QUANTUM MECHANICS	3-0-0--4	Path integral method of formulating quantum mechanics and its application to elementary quantum systems, formal scattering theory; Lippmann Schwinger formulation, scattering of particles with spin, stationary states, analytic properties of partial wave amplitudes, resonances, dispersion relations.
PHY615	NON-EQULIBRIUM STATISTICAL MECHANICS	3-0-0--4	Linear response theory, FokkerPlanck and Langvin equations, master equation; nucleation and spinodal decomposition, critical dynamics, Boltzmann equation.
PHY615A	NON-EQULIBRIUM STATISTICAL MECHANICS	3-0-0-0-9	Linear response theory, FokkerPlanck and Langevin equations, master equation; nucleartion and spinodal decomposition, critical dynamics, Boltzmann equation.
PHY616	SOFT MATTER PHYSICS	3-0-0-0-4	Introduction to Soft Matter, Forces, energies and time scales in soft matter, Thermodynamic aspects of inter molecular forces, van der Waals force, Hydrophobic and hydrophilic interaction, Interfacial phenomenon; wetting, adhesion and friction, Mechanical properties, Introduction to complex fluids, Fluid flow and hydrodynamic instabilities, Foams and emulsions, Polymers, colloids and Surfactants, Liquid crystals, Self assembly in soft matter, Experimental tools for soft matter. **Course Reference**: 1. Intermolecular and Surface Forces by Jacob N. Israelachvili (Academic Press, 1998); 2. Soft Condensed Matter by R. A. L. Jones (Oxford University Press, 2002); 3. Principles of Condensed Matter Physics by P. M. Chaikin and T. C. Lubensky (Cambridge University Press, 1995); 4. Hydrodynamic and hydromagnetic stability by S. Chandrashekhar (Oxford University Press, 1981); 5. Structured Fluids by Thomas A. Witten (Oxford University Press, 2004); 6. Structure and Rheology of Complex Fluids by Ronald G. Larson (Oxford University Press, 1999)
PHY616A	SOFT MATTER PHYSICS	3-0-0-0-9	Introduction to Soft Matter, Forces, energies and timescales in soft matter, Thermodynamic aspects of intermolecular forces, van der Waals force, Hydrophobic and hydrophilic interaction, Interfacial phenomenon; wetting, adhesion and friction, Mechanical properties, Introduction to complex fluids, Fluid flow and hydrodynamic instabilities, Foams and emulsions, Polymers, colloids and Surfactants, Liquid crystals, Self assembly in soft matter, Experimental tools for soft matter. **Course Reference** : 1. Intermolecular and Surface Forces by Jacob N. Israelachvili (Academic Press, 1998); 2. Soft Condensed Matter by R. A. L. Jones (Oxford University Press, 2002); 3. Principles of Condensed Matter Physics by P. M. Chaikin and T. C. Lubensky (Cambridge University Press, 1995); 4. Hydrodynamic and hydromagnetic stability by S. Chandrashekhar (Oxford University Press, 1981); 5. Structured Fluids by Thomas A. Witten (Oxford University Press, 2004); 6. Structure and Rheology of Complex Fluids by Ronald G. Larson (Oxford University Press, 1999).
PHY617	PHYSICS OF	3-0-0--4	Examples of sub cellular nanomachines of life; difference

	NATURAL NANO-MACHINES		between macroscopic and nanomachines: world of nanometer and picoNewton, stochastic dynamic sat low Reynolds number; experimental, computational and theoretical techniques: imaging and manipulating single molecules, fluorescence microscopy, optical weezers, and AFM; Langevin and Fokker Planck equations for Brownian rectifiers; power stroke vs. Brownian ratchet mechanisms for directed movements. Mechano chemistry of subcellular machines, energetics and efficiency of isothermal chemical machines far from equilibrium cytoskeleton associated nanomachines: intracellular motor transport; nucleotic based machines DNA/RNA helicase/polymerase, ribosome Gproteins switches and latches; membrane bound machines, translocation machines, molecular pumps, ATP synthase, flagellar motor; molecular sensors: hair cells; nanopistons and crawling of cells.
PHY621	ELECTRONIC STRUCTURE OF MATERIALS	4-0-0--4	One electron model, Born Oppenheimer approximation, Hartree & Hartree Fock approximation, density functional theory, local density approximation, beyond LDA. electrons in periodic solids, Blochs theorem, nearlyfree electron model, energy bands, Fermi surface, The tight binding method, APW method, OPW method, pseudo potential method, KKR method, LMTO method, the full potential methods. applications to different types of solids; electron in disordered solids, meanfield theories, coherent potential approximation, KKRCPA. Applications of KKRCPA, tight binding molecular dynamics, applications toclusters and solids, CarParinello methods and its applications to clustersand amorphous semiconductors, applications of electronic structure methodsto materials design.
PHY621A	ELECTRONIC STRUCTURE OF MATERIALS	3-0-0-0-9	One electron model, Born Oppenheimer approximation, Hartree & Hartree Fock approximation, density functional theory, local density approximation, beyond LDA. electrons in periodic solids, Blochs theorem, nearly free electron model, energy bands, Fermi surface, The tight binding method, APW method, OPW method, pseudopotential method, KKR method, LMTO method, the full potential methods. applications to different types of solids; electron in disordered solids, meanfield theories, coherent potential approximation, KKRCPA. Applications of KKRCPA, tight binding molecular dynamics, applications toclusters and solids, CarParinello methods and its applications to clusters and amorphous semiconductors, applications of electronic structure methods to materials design.
PHY622	CONDENSED MATTER II	3-0-0--4	Fermi liquid, second quantization, interaction picture, electron interaction; plasmons; electron phonon interactions; polarons, advanced methods of bandstructure calculations. Cooperative phenomena; magnetism and paramagnetism, superconductivity: experimental background, cooper pairs, BCS and Ginzburg Landau theories.

PHY624	MAGNETISM IN MATERIALS	3-0-0--4	Magnetism in atoms and ions; crystal field; dia and paramagnetism, ferro and antiferromagnetism; complex orders; experimental techniques; molecular fieldsand exchange interaction; direct interaction localized and itinerant electrons, band model of ferromagnetism. indirect interactions, R.K.K.Y. theory.
PHY627	COMPUTATIONAL SIMULATION METHODS IN PHYSICS	0-0---4	FORTRAN/C programming, structured programming, errors, numerical analysis, differentiation, integration, solution of differential equations, solution of Schrdinger equation, simulations of planetary motion, oscillatory motion, chaotic motion, molecular dynamics simulation, classical and tight binding molecular dynamics, simulation of Ar, density functional theory, CarParrinello simulation, Monte Carlo simulation, simulation of Ising model, quantum Monte Carlo simulation, genetic algorithms.
PHY628	TOPICS IN SEMICONDUCTOR	3-0-0--4	Tightbinding band structure; shallow impurities, deep impurities, density functional theory, many body theory of impurities, quantized Hall effect, metastability.
PHY629	PHYSICS AND TECHNOLOGY OF THIN FILMS	3-0-0--4	Introduction to thin films, nucleation theories and growth processes, PVD and CVD processes, epitaxial growth, microstructure, electronic transport, optical properties of thin films, size effects, physics and applications of thin films inselected areas.
PHY631	PHYSICS OF SEMICONDUCTOR NANOSTRUCTURES	3-0-0-0-4	Review of condensed matter and semiconductor physics, fabrication of quantum nanostructures, quantum structures and bandgap engineering. transportin quantum structures with applications, optical properties and applications, quantum mechanical effects in magneto transport, frontiers in current research.
PHY631A	PHYSICS OF SEMICONDUCTOR NANOSTRUCTURES	3-0-0-0-9	Review of condensed matter and semiconductor physics, fabrication of quantum nano structures, quantum structures and band gap engineering. transportin quantum structures with applications, optical properties and applications, quantum mechanical effects in magneto transport, frontiers in current research.
PHY634	LOW TEMPERATURE PHYSICS	3-0-0--4	Production of low temperatures; cryostat design and experimental techniques applied to low temperature; thermometry; specific heat, transport phenomena, thermal, electrical and magnetic properties; superconductivity, applications of superconductivity; superfluidity and associated phenomena.
PHY638	NUCLEAR TECHNIQUES IN SOLID STATE STUDIES	3-0-0--4	Different solid-state physics/materials science aspects which can bestudied using nuclear techniques. Rutherford backscattering, channeling, elasticrecoil detection analysis, positron annihilation, Mssbauer spectroscopy, ESCA etc.
PHY642	CONDENSED MATTER PHENOMENA IN LOW DIMENSIONAL MATERIALS	3-0-0--4	Characteristic length scales for quantum phenomena; scaling as a heuristic tool; scientific and technological significance of nanostructures and mesoscopic structures. brief introduction to quantum view of bulk solids, introduction to key ideas in transport and interaction of

			photons with material. Quantum structures: electronic properties: science and technology realizing low dimensional structures; MBE, MOCVD, Langmuir Blodgett films, novel processes; electronic properties of hetero structures, quantum wells, quantum wires, quantum dots, and superlattices, strained layer superlattices; transport in mesoscopic structures. resonant tunneling, hot electrons, conductance and transmission of nanostructures; principles of application of electronic devices. quantum structures: optical properties: optical process in low dimensional semiconductors. absorption. luminescence, excitons. application to lasers and photo detectors, transport inmagnetic field: magneto transport: transport in magnetic field, semi classical description, quantum approach, Aharonov Bohm effect, Shubnikov deHaas effect; introduction to quantum Hall effect.
PHY644	QUANTUM ELECTRONICS	3-0-0--4	Semiclassical theory of lasers, single and multimode operation, gas laser theory, ring and Zeeman lasers, coherence in lasers. nonlinear optical phenomena, Feynman diagrams in multiphoton problems.
PHY644A	QUANTUM ELECTRONICS	3-0-0-0-9	Semiclassical theory of lasers, single and multimode operation, gas laser theory, ring and Zeeman lasers, coherence in lasers. nonlinear optical phenomena, Feynman diagrams in multiphoton problems.
PHY646	COHERENT OPTICS	3-0-0--4	Fourier transforms, diffraction theory, coherence theory, two-dimensional systems theory, optical processing, holography, holographic inter ferometry and its applications; astronomical correlation inter ferometry, optical resonators, nonlinear optics, phase conjugation.
PHY647	ELECTRONICS	2-1-4--5	Survey of network theorems and network analysis, basic differential amplifier circuit, op amp characteristics and applications, simple analog computer, analog integrated circuits, PLL, etc., digital electronics, gates, flipflops, counters etc., transducers, signal averaging, lockin amplifier, D/A & A/D converter, multichannel analyzer etc., introduction to microprocessors.
PHY647A	ELECTRONICS	2-1-3--11	Survey of network theorems and network analysis, basic differential amplifier circuit, op amp characteristics and applications, simple analog computer, analog integrated circuits, PLL, etc. digital electronics, gates, flipflops, counters etc., transducers, signal averaging, lockin amplifier, D / A & A/D converter, multichannel analyzer etc., introduction to microprocessors.
PHY660	GENERAL RELATIVITY & COSMOLOGY	3-0-0--4	Machs principle. Riemannian geometry. Energy momentum tensor and Einsteins equations. Schwarzs child metric and singularities of space time. Post Newtonian approximations. spherically symmetric solutions of Einstein equations. Introduction to cosmology.
PHY660A	GENERAL RELATIVITY & COSMOLOGY	3-0-0-0-9	Machs principle. Riemannian geometry. Energy momentum tensor and Einsteins equations. Schwarzschild metric and singularities of space time. Post Newtonian approximations. spherically symmetric solutions of

			Einstein equations. Introduction to cosmology.
PHY680	PARTICLE PHYSICS	3-0-0--4	Natural units; evidence for 4 fundamental interactions, leptons and hadrons,historical introduction to particle zoo, relativistic kinematics, Lorentz invariant phase space, calculation of 2 and 3 body phase space, Dalitz plot, Mandelstam variables, crossing symmetry, isospin, flavour SU(2), strangeness & flavour SU(3), product representations and Young tableaux, the GellMann eightfold way,prediction of?, quark model, construction of hadronic wave functions, magnetic moment of the neutron, statistics of baryons & concept of colour; discovery of weak interactions, Fermi theory. IVB hypothesis, parity violation, mass problem, and decay; gauge theory, local U (1) gauge theory and Maxwell equations, Yang-Mills theories, SU (2) and SU (3) gauge theories, construction of SU (2) x U (1) gauge theory, gauge boson self interactions, spontaneous breaking of gauge symmetry, Abelian and nonAbelian cases, Goldstone theorem, Higgs mechanism, Ginzburg-Landau theory, construction of the Glashow-Salam-Weinberg model (outline only).
PHY680A	PARTICLE PHYSICS	3-0-0-0-9	Natural units; evidence for 4 fundamental interactions, leptons and hadrons,historical introduction to particle zoo, relativistic kinematics, Lorentz invariant phase space, calculation of 2 and 3body phase space, Dalitz plot, Mandel stam variables, crossing symmetry, isospin, flavour SU(2), strangeness & flavour SU(3), product representations and Young table aux, the GellMann eightfold way, prediction of?, quark model, construction of hadronic wave functions, magnetic moment of the neutron, statistics of baryons & concept of colour; discoveryof weak interactions, Fermi theory. IVB hypothesis, parity violation, mass problem, and decay; gauge theory, local U (1) gauge theory andMaxwell equations, YangMills theories, SU (2) and SU (3) gauge theories, construction of SU (2) x U (1) gauge theory, gauge boson self interactions, spontaneous breaking of gauge symmetry, Abelian and nonAbelian cases, Goldstone theorem, Higgs mechanism, Ginzburg Landau theory, construction of the Glashow Salam Weinberg model (outline only).
PHY681	QUANTUM FIELD THEORY	3-0-0--4	Lorentz and Poincar groups; relativistic wave equations; Lagrangian formalismfor fields; symmetry transformations and Nthers theorem; quantization of fields; divergences and renormalization; Yang Mills fields, spontaneous breakdown of symmetries and Goldstone theorem; Higgs phenomenon; unified models of fundamental interactions.
PHY681A	QUANTUM FIELD THEORY	3-0-0-0-9	Lorentz and Poincar groups; relativistic wave equations; Lagrangian formalismfor fields; symmetry transformations and Nthers theorem; quantizationof fields; divergences and renormalization; Yang Mills fields, spontaneous breakdown of symmetries and Goldstone theorem; Higgs phenomenon; unified models of fundamental interactions.
PHY682A	CONCEPTS OF PLASMA PHYSICS		This course has been broadly divided into eight chapters. [1]. Introduction [2]. Charged particle motion in

			electromagnetic fields [3]. Some basic plasma phenomena [4]. Collisional processes in plasmas [5]. Fluid description of plasmas [6]. Diffusion and mobility [7]. Equilibrium and instabilities [8]. Introduction to waves in plasmas.
PHY690	SPECIAL TOPICS IN PHYSICS	3-0-0--4	The course will deal with specialized topics of current interest in solid state, theoretical physics, molecular physics, or structure of matter. Detailed contents will be given by the instructor when the course is announced. If the numberof students is less than 5, this may be floated as a Reading Course with thepermission of DPGC.Every new course, other than Reading Courses, offered is numbered PHY 690A, PHY 690B, and so on, until PHY 690Z is reached. After that the cycle repeats from PHY 690A onwards.
PHY690A	GREEN NANOTECHNOLOGIES	3-0-0-0-9	The course will deal with specialized topics of current interest in solid state, theoretical physics, molecular physics, or structure of matter. Detailed contents will be given by the instructor when the course is announced. If the number of students is less than 5, this may be floated as a Reading Course with the permission of DPGC. Every new course, other than Reading Courses, offered is numbered PHY 690A, PHY 690B, and so on, until PHY 690Z is reached. After that the cycle repeats from PHY 690A onwards.
PHY692	MEASUREMENT TECHNIQUES	3-0-0--5	Typical experiments in various areas is physics; vacuum techniques; transducers: temperature, pressure, charge particles, photons, etc; electronic noise; survey of analog and digital I/Cs; signal processing, data acquisition andcontrol systems; data analysis evaluation.
PHY692A	MEASUREMENT TECHNIQUES	3-0-3-0-12	Typical experiments in various areas is physics; vacuum techniques; transducers: temperature, pressure, charge particles, photons, etc; electronic noise; survey of analog and digital I/Cs; signal processing, data acquisition and control systems; data analysis evaluation.
PHY781	HIGH ENERGY PHYSICS II	3-0-0--4	Current topics in Particle Physics and quantum field theory.
PHY781A	HIGH ENERGY PHYSICS II	3-0-0-0-9	Current topics in Particle Physics and quantum field theory.
PHY799	RESEARCH	----	To be registered by PhD. students from Semester I itself, and by M.ScPh.D.(DualDegree) students from Semester V onwards.
PHY799A	PH D THESIS	0----4	Ph. D. Thesis
SE301	QUANTUM PHYSICS	3-1-0-0-4	Origin of quantum theory and related experiments, Wave Particle duality for photons and material particles, Wave function and its born interpretation, Relation with measurement of dynamical variables, function as definite position and plane wave as definite momentum wave function, Wavepacket as superposition of functions and of plane waves, Position momentum Uncertainty Principle, Gaussian wave packets, Applicability of classical physics on the basisof uncertainty product. Operator formulation, commuting operators, simultaneous eigen functions,

			degenerate eigen functions. Schrodinger equation for time evolution, Stationary states, spread of free particle wave packets, Time energy uncertainty, Natural line width of spectral lines. Probability currents and theirrelation with the flux in beams of particles. Square well potentials, Practical examples like metal vacuum interface, Contactpotential between metals, Bilayerand sandwiched thin film etc., Bound states in deep potential well and finite potential well, Double well potentials and examples like Ammonia inversion, Delta function potentials and examples like electron sharing in covalent bonds. Kronig Penny model of 1D crystals and formation of energy bands. Linear harmonic oscillator, outline of getting stationary states, Molecular vibrations and spectroscopy. Barrier Tunneling, Examples of adecay, nuclear fission, fusion inthe Sun, Cold emission, Scanning tunneling microscope, principle of tunnel diodeetc; Angular momentum operators, eigen values and eigen functions, Spinangular momentum, hydrogen atom using Coulomb interaction, structure of Haline due to ls interaction (derivation not needed).
SE305	PHYSICS OF NON-EQUILIBRIUM PHENOMENA	3-1-0--4	INTRODUCTION: Examples of nonequilibrium phenomena(i) Glass transition; (ii)Nucleation; (iii) Phase separation; Experimental probes: Dynamic scattering; inelastic neutron scattering, THEORETICAL TOOLS: Two alternative theoretical approaches (a) Langevin equation dissipation, nonlinearity and noise; Illustration with translational Brownian motion; (b) Fokker Planck equation diffusion and drift; Illustration with (i) translational Brownian motion, (ii) rotational Brownian motion. Master equation loss and gain of probabilities; concept of detailed balance. METASTABILITY AND BISTABILITY: Kramers theory of thermally activated barrier crossing applications in (i) chemical reactions (ii) rock magnetism. Enhancing signals with the help of noise applications of stochastic resonance in (a) nonlinear optics, (b) solid state devices, (c) neuroscience, (d) molecular motors and biological locomotion. Becker Doring Theory of homogeneous nucleation and its modern extensionsapplications in (a)condensation and (b) crystallization. UNSTABLE STATES: Allen Cahn scenario of interfacial dynamics and domain growth applications to domain growth inquenched magnets; Lifshitz Slyozov arguments for phase separation and its generalizations applications to (a) alloys, (b) fluid mixtures, (c) polymer mixtures. Theory of phase separation controlled by topological defects application to liquid crystals. Theory of coarsening of Cellular Patterns applications to soap froths (e.g., shaving foams). NONEQUILIBRIUM STEADY STATES IN DRIVEN SYSTEM: Driven systems of interacting particles applications to vehicular traffic; Driven surfaces applications in molecular beam epitaxy (MBE).
SE305A	PHYSICS OF NON-EQUILIBRIUM	3-1-0-0-11	INTRODUCTION: Examples of nonequilibrium phenomena (i) Glass transition; (ii) Nucleation; (iii) Phase

	PHENOMENA		separation; Experimental probes: Dynamic scattering; inelastic neutron scattering, THEORETICAL TOOLS: Two alternative theoretical approaches (a) Langevin equation dissipation, nonlinearity and noise; Illustration with translational Brownian motion; (b) Fokker Planck equation diffusion and drift; Illustration with (i) translational Brownian motion, (ii) rotational Brownianmotion. Master equationloss and gain of probabilities; concept of detailed balance. METASTABILITY AND BISTABILITY: Kramers theory of thermallyactivated barrier crossing applications in (i) chemical reactions (ii) rockmagnetism. Enhancing signals with the help of noise applications of stochastic resonance in (a) nonlinear optics, (b) solid state devices, (c) neuroscience, (d) molecular motors and biological locomotion. Becker Doring Theory of homogeneous nucleation and its modern extensions applications in (a)condensation and (b) crystallization. UNSTABLE STATES: Allen Cahn scenario of interfacial dynamics and domain growth applications to domain growth inquenched magnets; LifshitzSlyozov arguments for phase separation and its generalizations applications to (a) alloys, (b) fluid mixtures, (c) polymer mixtures. Theory of phase separation controlled by topological defects application to liquid crystals. Theory of coarsening of Cellular Patterns applications to soap froths (e.g., shaving foams). NONEQUILIBRIUM STEADY STATES IN DRIVEN SYSTEM: Driven systems of interacting particles applications to vehicular traffic; Driven surfaces applications in molecular beam epitaxy (MBE).
SE307	QUANTUM PROCESSES IN LOW DIMENSIONAL SEMICONDUCTORS	3-0-0--4	Course Outline: Characteristic length scales for quantum phenomena; Scalingas a heuristic tool; Scientific and Technological significance of nanostructures and mesoscopic structures. Brief introduction to quantum view of bulk solids, Introduction to key ideas in transport and interaction of photons with material. Quantum Structures: Electronic Properties: Science and technology realizing low dimensional structures; MBE, MOCVD, Langmuir Bloddgett films, novel processes; Electronic properties of Heterostructures, Quantum wells, Quantum wires, Quantum dots, and superlattices, Strained Layer Superlattices; Transport inMesoscopic Structures. Resonant Tunneling, Hot Electrons, Conductance and Transmission of Nanostructures. Principles of application of electronic devices. Quantum Structures: Optical Properties: Optical process in low dimensional semiconductors. Absorption. Luminescence, Excitons. Application to lasers and photo detectors, Transport in Magnetic Field: Megneto transport: Transport in Magnetic Field, Semiclassical description, Quantum Approach, Abaranov Bohm effect, Subnikov de Haas effect; Introduction to Quantum Hall effect.
SE308	ENERGY	3-0-0--4	Indian and global energy resources, current energy exploitation, energy demand, energy planning, renewable energy sources, wind energy, energy from water, solar

			energy, energy from mineral oils, nuclear energy, energy for sustainable development, environmental concerns.
SE309	PRINCIPLES OF LASERS & THEIR APPLICATIONS	3-0-0--4	Gaussian Optics, Optical Resonators and their Mode Structure; Atomic levels, Absorption, Spontaneous and Stimulated emission, Einstein coefficients; Rate Equations, Population Inversion, Gain media, 3 and 4 level lasers; CW & Pulsed Lasers, QSwitching, modelocking, Short pulses; Ar+, CO2, Nd: YAG, diode lasers, etc.; Metrology, Optical Communication, Materials Processing, Holography, Medical Applications.
SE311	PHYSICS OF UNIVERSE	3-0-0-0-4	Astronomical observations and instruments, Photometry; Stellar spectra and structure; Stellar evolution, nucleosynthesis and formation of elements; Variable stars; Compact stars (white dwarfs. Neutron stars, black holes; Star clustersand Binary stars; Galaxies, their evolution and origin; Active galaxies and quasars; Big bang model of the universe, early history of the universe, cosmic microwave background radiation.
SE312	ORDER AND CHAOS	3-0-0-0-4	Dynamical Systems; Nonlinear dynamics of one dimensional flows, Fixed point, linear stability analysis, bifurcations; Nonlinear dynamics of two dimensional flows, Phase space, equilibrium, Limit cycle, stability, bifurcations; Periodicity, disturbed periodicity; Nonlinear dynamics of 1D and 2D maps, fixed point, stability, Poincare section; Routes to chaos Period doubling, quasi periodicity and intermittency, Universality, Renormalization; Measurement of chaos, Lyapunov exponent, entropy; Strange attractors, fractal geometry and fractal dimension; Examples from Sciences and Engineering.
SE312A	ORDER AND CHAOS	3-0-0-0-9	Dynamical Systems; Nonlinear dynamics of one dimensional flows, Fixed point,linear stability analysis, bifurcations; Nonlinear dynamics of two dimensional flows, Phase space, equilibrium, Limit cycle, stability, bifurcations; Periodicity, disturbed periodicity; Nonlinear dynamics of 1D and 2D maps, fixed point,stability, Poincare section; Routes to chaos Period doubling, quasiperiodicity and intermittency, Universality, Renormalization; Measurement of chaos, Lyapunov exponent, entropy; Strange attractors, fractal geometry and fractal dimension; Examples from Sciences and Engineering.
SE313	MODERN OPTICS	3-0-0--4	Review of Maxwell's and electromagnetic wave equations; Wave propagation in anisotropic media; Polarized light; Diffraction from circular aperture and concept of resolution; Fourier transforms and Fourier optics, Spatial filtering, and Image Processing; Coherence, Holography; Optical Waveguides and integrated optics; Optical fibres, Optical sources (LED, Lasers etc.) and detectors, and optical communication; Electro and magneto optic effects; Laser matter interaction.
SE314	CLASSICAL MECHANICS	3-0-0--4	Review of the Newtonian mechanics; Lagrangian Mechanics, Generalized coordinates, constraints, Principle

			of virtual work, Lagranges equation, Calculusof variations; Central forces, Collisions, Scattering; Small oscillations, Anharmonic oscillators, Perturbation theory, Forced oscillators; Hamiltons Equations, phasespace & phase trajectories, canonical transformations, Poisson brackets, Hamilton Jacobi theory; Rigid body dynamics; Nonlinear Dynamics.
SE314A	CLASSICAL MECHANICS	3-0-0-0-9	Review of the Newtonian mechanics; Lagrangian Mechanics, Generalized coordinates, constraints, Principle of virtual work, Lagranges equation, Calculusof variations; Central forces, Collisions, Scattering; Small oscillations, An harmonic oscillators, Perturbation theory, Forced oscillators; Hamiltons Equations, phasespace & phase trajectories, canonical transformations, Poisson brackets, Hamilton Jacobi theory; Rigid body dynamics; Nonlinear Dynamics.
SE315	SPECIAL & GENERAL RELATIVITY	3-0-0-0-4	Special Relativity, Empirical evidence for the constancy of c, Frames o freferences; Lorentz transformations; relativity of simultaneity; twin and other paradoxes; Transformation laws for velocity, momentum, energy; Mass energy equivalence; force Equations; Kinematics of decays and collisions; Maxwell’s equations in covariant form; Representations of the Lorenz Group and SL(2,C); Introduction to General Relativity; Principle of equivalence; Machs principle; Riemannian geometry; Christoffel symbols, the curvature and stress Energy tensors; the gravitational field equations; Geodesics and particle trajectories; Schwarzchild solution; Experimental tests; Basic cosmology; FRWmetric; Cosmological expansion; Cosmic Microwave background; Helium abundance; anisotropies in the CMB.
SE315A	SPECIAL & GENERAL RELATIVITY	3-0-0-0-9	Special Relativity, Empirical evidence for the constancy of c, Frames ofreferences; Lorentz transformations; relativity of simultaneity; twin and other paradoxes; Transformation laws for velocity, momentum, energy; Mass energy equivalence; force Equations; Kinematics of decays and collisions; Maxwell’s equations in covariant form; Representations of the Lorenz Group and SL(2,C);Introduction to General Relativity; Principle of equivalence; Machs principle;Riemannian geometry; Christoffel symbols, the curvature and stress Energytensors; the gravitational field equations; Geodesics and particle trajectories; Schwarzchild solution; Experimental tests; Basic cosmology; FR Wmetric; Cosmological expansion; Cosmic Microwave background; Helium abundance;anisotropies in the CMB.
SE316	STATISTICAL MECHANICS	3-1-0--4	1.Review of Thermodynamics; 2. Basic Principles and Applications of StatisticalMechanics; 3. Ideal Quantum Gases; 4. Interacting Systems;5. Theories of PhaseTransitions; 6. Computer Simulations; 7. Elementary Concepts of Nonequilibrium Stat. Mechanics
SE316A	STATISTICAL MECHANICS	3-1-0-0-11	1.Review of Thermodynamics; 2. Basic Principles and Applications of StatisticalMechanics; 3. Ideal Quantum

			Gases; 4. Interacting Systems; 5. Theories of PhaseTransitions; 6. Computer Simulations; 7. Elementary Concepts of Nonequilibrium Stat. Mechanics
SE317	INTRODUCTION TO ATOMIC & NUCLEAR PHYSICS	3-1-0--4	Quantum mechanics of one and two electron atoms, Many electron atoms, Centralfield approximation, ThomasFermi approximation, Molecular binding, LCAO, LCMO and VB methods, Hydrogen molecules, Molecular spectra, Raman effect, Lasers.
SE321	THERMAL PHYSICS	3-1-0-0-4	Principles of thermodynamics (with applications to simple fluids), applications of thermodynamics: concept of thermodynamic state, extensive and intensive variables; heat and work, internal energy function and the first law of thermodynamics; fundamental relation and equations of state; concepts of entropy and temperature as conjugate pair of variables; second law of thermodynamics, entropy maximum and energy minimum principles; thermodynamic potentials: enthalpy, Helmholtz potential, Gibbs potential;conditions of equilibrium, concepts of stable, metastable and unstable equilibrium;components and phases, GibbsDuhem relations; first order phase transitions and Clausius Clapeyron equation; concepts associated with critical and multicritical phenomena, some chosen applications from surfaces and interfaces, chemical reactions (magnetic, dielectric and superconducting); heat engines and black body radiation; elementary kinetic theory of gases: equilibrium properties pressure and equation of state; transport processes momentum transport and viscosity, energy transport and thermal conductivity, charge transport & electrical conductivity (without using Boltzmann transport equation); entropy, multiplicity and disorder: entropy measures multiplicity rather than disorder, illustration with simple examples; Maxwell's demon; qualitative justifications of laws of thermodynamics (without introducing ensembles), thermodynamics of irreversible processes: entropy production.
SE322	NATURAL NANO MACHINES	3-0-0--4	Examples of nanomachines in living cells; differences between macroscopic andnano machines; world of nanometer and pico Newton; stochastic dynamics of nanomachines; experimental, computational and theoretical techniques; imaging and manipulating single machines; Power stroke versus Brownian ratchet mechanism; mechanochemistry of nanomachines; energetics and efficiency of nanomachines; intracellular cargo transporters; nanosize unzippers; nanosized engines for polymerization of macromolecules; exporters/importers of macromolecules; packaging machines; switches and latches; ion pumps; flagellar motor; rotary motors of ATP synthesizer; molecular sensors hair cells; nanopistons and cell crawling.

LASER TECHNOLOGY

Template?

DEPARTMENT OF LT			
Course ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
LT601	INTRODUCTION TO LASERS	3-0-0--4	Introduction to general lasers and their types, Brief intro. quantum physics, Schrodinger wave eqn., Atomic systems, emission and absorption processes, Population inversion, gain, optical cavities, three and four level lasers, CW and pulsed lasers, Q switching and mode locking, Physics of gas discharge, Atomic, Ionic, molecular, liquid, and excimer lasers, Optical pumping.
LT611	LASER SYSTEMS AND APPLICATIONS	3-0-0--4	Atomic, ionic, molecular, excimer and liquid laser systems and applications, Solid state lasers. Short Pulse generation and measurement. Laser applications in medicine and surgery, Materials processing, Optical Communication Lasers, Metrology and LIDAR.
LT631	INTRODUCTION TO COHERENT AND LASER OPTICS	3-0-3--4	Maxwell's eqns. and electromagnetic waves, Wave properties of light and propagation. Waveguides, Optical resonators. Ray Optics, Matrix methods, Optical Anisotropic materials. Interference and interferometers, Diffraction and Fourier Optics, Optical components (Laser mirrors, windows, Polarizors, Holography, Meteorology).
LT699	M TECH THESIS	----	M. Tech. Thesis
LT799	PHD THESIS	----	Ph. D. Thesis

STA?

Template?

DEPARTMENT OF STA			
Course ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
STA799	Ph. D THESIS	0-0-0--	Ph. D Thesis
STA800	RESEARCH	----	RESEARCH