Department of Mechanical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

24-050 Study Abroad

Fall
Mechanical Engineering students studying abroad through other institutions are registered for this zero-unit place holder "course." Prior to being enrolled for study abroad, the student must have completed an Office of International Education "Study Abroad Transfer Credit (SATC) Form," which must be signed by their academic advisor in Mechanical Engineering.

24-101 Fundamentals of Mechanical Engineering

Fall and Spring: 12 units
The purpose of this course is to introduce the student to the field of mechanical engineering through an exposition of its disciplines, including structural analysis, mechanism design, fluid flows, and thermal systems. By using principles and methods of analysis developed in lectures, students will complete two major projects. These projects will begin with conceptualization, proceed with the analysis of candidate designs, and culminate in the construction and testing of a prototype. The creative process will be encouraged throughout. The course is intended primarily for CIT first year students.

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-104 TechSpark: Modern Making

Fall and Spring: 3 units
This course teaches the fundamental skills needed to plan, develop, and prototype a functional device. A significant portion of the course will cover introductory-level use of 3D CAD software, 3D printers, and Arduino. Homework assignments are important for reinforcement of skills learned, and the utilization of these skills will be applied to a self-directed project. 3-unit mini (7-weeks)

Course Website: http://www.cmu.edu/me (http://www.cmu.edu/me/)

24-105 Maker Series: Intro to Laser Cutting & Engraving

Fall and Spring: 1 unit
This course teaches the safe operation of the laser cutter-engraver machine through structured hands-on activities. A significant portion of this course is dedicated to learning joinery, color mapping, and material selection for prototyping. Homework assignments are important for reinforcement of skills learned, and are flexible for students to complete guided or self-directed projects. 1-unit micro (2-weeks)

24-200 Maker Series: Intro to Manual Machining

Fall and Spring: 1 unit
This course teaches safe operation of manual machining equipment through structured hands-on activities. A significant portion of the course is dedicated to learning subtractive manufacturing, the industrial standard for the mass manufacture of products around the world. The skills learned in this course can be applied to fabricate durable components for design projects, research equipment, and extracurricular activities. 1-unit mini (7-weeks)

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-201 Special Topics: TechSpark: Project Fabrication and Assembly

Fall: 1 unit
This course teaches the fundamental skills of fabrication and assembly by progressing through a hands-on building project. A significant portion of the course is dedicated to safely operating hand and power tools, using common components as parts for assemblies, and incorporating moving mechanisms within housings. This class provides a foundational experience that can be built upon in future project classes. 1-unit mini (7-weeks)

24-202 Introduction to Computer Aided Design

Fall and Spring: 1 unit
Introduction to computer aided mechanical design using SolidWorks 3D CAD software. Includes the creation and analysis of components and assemblies, generation of drawings, and exporting for manufacture. Two hours of guided computer lab work each week. Prerequisite: Undergraduate Mechanical Engineering standing
Prerequisites: 24-101 or 24-104

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-203 TechSpark: Manual Machining

Fall and Spring: 3 units
This course teaches the safe operation of manual machining equipment, including knee mill and lathe through structured hands-on activities. A significant portion of this course is dedicated to reading technical drawings, and then fabricating those components using equipment. Homework assignments are important for reinforcement of skills learned, and a self-directed project will utilize known techniques in new applications. This course is required to use the student machine shop at TechSpark. 3-unit mini (7-weeks)

24-204 TechSpark: Metal Jewelry

Fall and Spring: 3 units
This course teaches introductory-level metal jewelry fabrication through structured hands-on activities. Students will learn to safely use various tools and metal working techniques including cold forging, investment casting, bezel settings, soldering, and patinas. Homework assignments are important for reinforcement of skills learned, which will include creating personal jewelry items such as earrings, pendants, and rings. This course is required to use the hot metals room at TechSpark. 3-unit mini (7-weeks)

24-205 TechSpark: Welding

Fall and Spring: 2 units
This course teaches the safe operation of welding equipment through structured hands-on activities. A significant portion of the course is dedicated to learning workpiece setup, material selection, and weldability assessment for introductory-level projects. Homework assignments are important for reinforcement of skills learned, and the utilization of these skills will be applied to a self-directed project. This course is required to use the welding equipment at TechSpark. 2-unit mini (7-weeks)

24-206 TechSpark: Wood Working I

Fall and Spring: 3 units
This course teaches the safe operation of wood working equipment, including table saw, panel saw, and miter saw through structured hands-on activities. A significant portion of the course is dedicated to learning optimal workflow, tool selection, and equipment selection for introductory-level projects. Homework assignments are important for reinforcement of skills learned. This course is required to use the student wood shop at TechSpark. 3-unit mini (7-weeks)

24-207 TechSpark: Wood Working II

Fall and Spring: 1 unit
This course builds upon previous skills taught in 24-206 TechSpark: Wood Working I. A significant portion of the course is dedicated to learning wood material properties, joinery methods, and CNC router machine for mid-level projects. Homework assignments are important for reinforcement of skills learned. This course is required to use the CNC wood router in the student wood shop at TechSpark. 3-unit mini (7-weeks)
Prerequisite: 24-206

24-210 Special Topics: Maker Series: Inventive Projects

Fall and Spring
This course supports students in pursuing a self-defined project. Students will apply their preexisting access to equipment towards prototyping an inventive project, either as an individual or a group member. Students will receive weekly one-on-one consultations with the instructor to conduct project planning, design for fabrication, prototype testing, and more.
This course is useful for students interested in initiating, progressing, and/or completing a prototyping project for research, student orgs, entrepreneurship, hobbies, or other interests.
Prerequisites: 24-101 or 24-206 or 24-104 or 24-200 or 24-204 or 24-205 or 24-105

24-212 Special Topics: Maker Series: Make It Move

Fall and Spring: 9 units
This course explores many types of mechanisms for movement and their optimal applications. A significant portion of class will be dedicated to hands-on labs, during which objects are dissected to reveal their methods of movement. Springs, gears, motors, pneumatics, levers, wheels, bearings, and other components will be analyzed for their roles in energy storage, power delivery, and motion. These lessons will culminate in a complete design project, for which students will use rapid fabrication equipment to make a prototype that moves.
Prerequisites: 24-104 or 24-101

Course Website: https://www.meche.engineering.cmu.edu/

24-213 Special Topics: Citizen Science: Sensors, Makers and the Environment

Spring: 9 units
This course will introduce students to technical aspects of citizen science, using air pollution as a case study. Students will learn about important air pollutants and the environmental regulations that govern these pollutants in the U.S. Students will be introduced to data quality requirements for applications ranging from regulatory pollutant monitoring to education/outreach. Students will also learn about operating principles for both laboratory- and consumer-grade pollutant monitoring equipment. The class will culminate in a project where student teams will design, construct, and test a low-cost air pollutant monitoring system. The groups will then deploy these sensor packages to collect and present their data. The project will use the TechSpark maker space. It is primarily aimed at non-engineering majors.

24-214 IDeATe Special Topics: Mazes

Fall: 9 units
Labyrinths have been a part of our culture for millennia, from Greek myths to Renaissance palaces, to childrens pastime. The mental challenge of traversing a maze combines both the intuitive and the systematic processes that delight our human experience. As our society becomes more sedentary, the rebirth of the physical maze can serve as a bridge from the pure mental exercise to increased mobility, especially if they are modernized to become more dynamic, more adaptable, more portable, more modern. This course will allow students to study the history of labyrinths and to discover how to design and build fun, challenging, technically-enhanced, and community-engaging mazes.

24-215 IDeATe Special Topics: Smart Furniture

All Semesters: 9 units
As we integrate personal technology into our daily lives, the spaces we inhabit evolve from purely functional, comfortable, and efficient locations for work, play, and relaxation to statements on our lifestyle, tastes, and self-image. Of the attributes in our spaces we can control, furniture has the greatest effect on how our living spaces reflect our personalities. This course will thus focus on the design and physical prototyping of smart, multi-use, transforming furniture that can elevate our modern living spaces to unique showcases of our individuality.

24-221 Thermodynamics

Fall: 10 units
Temperature and thermometry; equations of state for fluids and solids; work, heat, and the first law; internal energy, enthalpy, and specific heats; energy equations for flow; change of phase; the second law, reversibility, absolute temperature, and entropy; combined first and second laws; availability; power and refrigeration cycles. Applications to a wide range of processes and devices. 3 hrs. lec., 1 hour recitation
Prerequisites: (33-141 or 33-151 or 33-106 or 33-121) and 21-122 Min. grade C and 24-101

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-231 Fluid Mechanics

Spring: 10 units
Hydrostatics. Control volume concepts of mass, momentum, and energy conservation. Euler's and Bernoulli's equations. Viscous flow equations. Head loss in ducts and piping systems. Dimensional analysis and similitude as an engineering tool. Measurement techniques. 3 hrs. lec., 1 hr. rec.
Prerequisites: (33-151 or 33-141 or 33-106) and 21-122 Min. grade C

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-251 Electronics for Sensing and Actuation

Fall and Spring: 3 units
Mechanical engineers design, build, and troubleshoot basic circuits that perform signal conditioning on sensor measurements and provide power amplification for actuation. This course covers the basics of passive circuit design, applications of operational amplifiers, and the use of transistors to amplify low power signals coming from microcontrollers. Lecture materials are coupled with hands-on in-class exercises and homework assignments using the Arduino to interface with sensors and actuators.
Prerequisite: 24-101

24-261 Mechanics I: 2D Design

Fall: 10 units
This is the first course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. In the first semester, students review and extend methods of 2D statics to study single and multiple bodies, such as structures and machines. Internal loads in 2D are defined and quantified, followed by a study of stresses and strains under axial loading, bending and shear. Students will also learn engineering design process methods and skills, including concept design, detailed design, analysis, fabrication, and testing. As topics are introduced and applied by students in hands-on assignments, they will compare theoretical computations and experimental testing of their design ideas, so as to reinforce fundamentals and practice the engineering design process.
Prerequisites: 21-122 Min. grade C and (33-106 or 33-121 or 33-151 or 33-141) and 24-101

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-262 Mechanics II: 3D Design

Spring: 10 units
This is the second course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. In the second semester, students extend their foundation in 2D statics to the analysis of 3D engineering systems, including determination of reactions at connections and internal loads. Friction, shear stress, and shear strain are introduced, followed by a study of stresses and deformation in torsion. Multiaxial stresses, such as those occurring in combinations of torsion and bending or in pressure vessels, are studied. Stress transformations are introduced, as well as the formulation of simple failure criteria. Students will expand their engineering design skills through team-based hands-on and computational projects that utilize stress and failure analysis of 3D engineered systems. In addition, students will learn elementary aspects of machine design and catalog selection to support projects. Altogether, students will learn to express ideas in sketches, interpret and create engineering drawings, model detailed shapes with CAD tools, analyze product performance with CAE tools, choose materials and manufacturing schemes, and create and test prototypes.
Prerequisites: (33-151 or 33-141 or 33-106) and 24-261

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-280 Special Topics: C++ Programming for Engineers

Fall and Spring: 9 units
Using the C++ programming language as a platform, this course serves as an intermediate-level programming course with a strong emphasis on software requirements for engineering applications. Students will refine and enhance their coding skills while applying their mathematical, analytical and design backgrounds. Topics covered include data structures, algorithm design, numerical computation, modular programming, data modeling, interactive graphics, object-orientation, and user interfaces, all in an engineering-specific domain.
Prerequisites: 15-110 or 15-112

Course Website: http://www.cmu.edu/me (http://www.cmu.edu/me/)

24-281 Introduction to Scientific Computing

Fall and Spring: 2 units
This course provides an introduction to scientific computing with Matlab for engineers. The course introduces the basics of Matlab syntax and programming, data analysis, visualization, curve fitting and interpolation, symbolic computation, differential equations, and debugging. The use of Matlab in solving mechanical engineering applications will be demonstrated.

Course Website: https://www.meche.engineering.cmu.edu/

24-291 Environmental Systems on a Changing Planet

Fall: 9 units
This course introduces the interconnected environmental systems that regulate our climate and ecosystems, providing the resources required to sustain all life, including human societies. These systems are the fascinating connections between the oceans, atmosphere, continents, ecosystems, and people that provide our planet with resources that all life depends on. Human activities disrupt these natural systems, posing critical threats to the sustainable functioning of environmental systems. We will explore how solar and biochemical energy moves through the Earths interconnected systems, recycling nutrients; how complex environmental systems function to produce critical resources such as food and water; and how human activities interfere with these systems. Earth science concepts will be used to explain the relationship between climate zones and biomes, the stability of the Earth's climate in the Holocene, and the instability in the current Anthropocene. Case studies include the interplay between climate change feedbacks, wildfires, ecosystems, and agricultural systems; the hazards that everyday chemical toxins pose to ecosystems and human health and reproduction; and growing threats to ecosystem health and biodiversity. We will also develop the relevant science and information literacy required to understand current issues that are frequently debated in the public sphere, and connect these to environmental justice.

24-292 Renewable Energy Engineering

Intermittent: 9 units
Introduction to engineering principles of various renewable energy systems, including the following topics: background on climate change and carbon sequestration, engineering analysis of renewable energy systems such as solar photovoltaic, (solar thermal), wind power, hydropower, wave energy, bio mass energy, geothermal energy, and hydrogen based fuel cells. In addition, transitional energy systems such as nuclear power and advanced combined cycles will be introduced. Both engineering performance and present state of development will be discussed. Students will review and present their progress on various subjects, which will be selected based on personal interest.
Prerequisites: 33-106 or 33-141

Course Website: http://www.andrew.cmu.edu/user/satbirs/24292/

24-300 TechSpark: CNC Machining

Fall and Spring: 2 units
This course builds upon previous skills taught in TechSpark's Manual Machining class. A significant portion of the course is dedicated to learning 2.5D Computer Aided Manufacturing (CAM) software, equipment setup, and machine operation. Homework assignments are important for reinforcement of skills learned, and the utilization of these skills will be applied to a self-directed project. This course is required to use the CNC milling machines in the student machine shop at TechSpark. 2-unit mini (7-weeks)
Prerequisites: 24-200 or 24-203

24-302 Professional Development for Mechanical Engineers

Fall and Spring: 2 units
This course prepares students to communicate verbally as an engineer. Students will practice and receive feedback on their oral communication in a range of contexts, including formal presentations, elevator pitches, job interview questions, and communicating technical concepts to non-engineers. In addition, students will be introduced to a range of professional topics, including ethical decision-making, communicating in global contexts, negotiation strategies, and strategies for overcoming implicit bias. Student grades will be based upon weekly homework assignments, formal presentations, and class participation.

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-311 Numerical Methods

Spring: 10 units
Use of numerical methods for solving engineering problems with the aid of a digital computer. The course will contain numerical methods such as roots of equations, linear algebraic equations, optimization, curve fitting, integration, and differential equation solving. MATLAB will be used as the programming language. Programming cluster laboratory times will be available twice a week. Problems will be drawn from all fields of interest to mechanical engineers. 3 hrs. lecture plus lab
Prerequisites: 21-260 and 21-254

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-321 Thermal-Fluids Experimentation

Spring: 12 units
Thermal-Fluids Experimentation Spring: 12 units This is a capstone course for the thermal-fluids core-course sequence. This course covers techniques of measurement, uncertainty analysis, and realization of systems, which demonstrate fundamental principles in thermodynamics, fluid mechanics, and heat transfer. The principles of designing thermal experiments are also integrated into this course.
Prerequisites: 24-221 and 24-322 and 24-231

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-322 Heat Transfer

Fall: 10 units
Introduction to basic concepts of engineering heat transfer. Steady and transient heat conduction in solids, including the effect of heat generation. Finned surfaces. Correlation formulas for forced and free convection, condensation, and boiling. Design and analysis of heat exchangers. Radiation heat transfer. Problems in combined convection and radiation. Measurement techniques. 3 hrs. lec., 1 hr. recitation.
Prerequisites: 24-221 and 24-231 and 21-260 Min. grade C

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-334 Introduction to Biomechanics

Fall: 9 units
This course covers the application of solid and fluid mechanics to living tissues. This includes the mechanical properties and behavior of individual cells, the heart, blood vessels, the lungs, bone, muscle and connective tissues as well as methods for the analysis of human motion.
Prerequisite: 24-231

Course Website: http://www.cmu.edu/me/

24-341 Manufacturing Sciences

Spring: 9 units
This course has two broad concerns: an introductory review of manufacturing systems organization and a review of common manufacturing processes from the point of view of design for manufacturability. The features of mass and batch production are quantitatively considered. The basic principles of group technology and production planning are outlined. The use of computers in manufacturing is described, together with a review of the current capabilities of industrial robots. Students will be involved in weekly seminars, which will describe the basic features of common manufacturing processes, including metal machining, metal forming, polymer processing, casting techniques, joining techniques, ceramic processing, and powder processing. Case studies from industry and films may be used. 3 hrs. rec.
Prerequisite: 24-262

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-351 Dynamics

Fall: 10 units
This first course on the modeling and analysis of dynamic systems concentrates on the motion of particles, systems of particles, and rigid bodies under the action of forces and moments. Topics include the kinematics of motion in rectangular, polar, and intrinsic coordinates; relative motion analysis with multiple reference frames; and planar kinetics through the second law, work-energy method, and impulse-momentum method. Time and frequency domain solutions to first and second order equations of motion are discussed. 3 hrs. lec. 1 hr rec.
Prerequisites: 21-260 Min. grade C and 24-101

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-352 Dynamic Systems and Controls

Fall and Spring: 12 units
This second course on the modeling and analysis of dynamic systems emphasizes the common features, which are exhibited by physical systems that include mechanical, hydraulic, pneumatic, thermal, electrical, and electromechanical elements. State equations and the concepts of equilibrium, linearization, and stability are discussed. Time and frequency domain solutions are developed. 4 hr. lec.
Prerequisites: (24-351 and 21-260 Min. grade C and 33-107 and 24-251) or (24-251 and 33-142 and 24-351 and 21-260 Min. grade C) or (33-152 and 24-251 and 21-260 Min. grade C) or (24-351 and 24-251 and 21-260 Min. grade C and 33-132)

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-354 Mechatronics Applications in Mechanical Engineering

Fall: 9 units
Most modern products contain elements of sensing, actuation, and control. This course builds on concepts from Dynamic Systems and Control to design simple mechatronic systems. Topics include modeling and selection of sensors and actuators, measurement systems, digital signal processing, microcontroller architectures, and the basics of state space control methods; these topics are taught in the context of integration with mechanical systems. This course includes a substantial project component in which students design, build, and test a mechatronic system through a series of subsystem prototypes and systems integration.
Prerequisite: 24-352

Course Website: http://www.cmu.edu/me/

24-358 Culinary Mechanics

Intermittent: 9 units
This course discusses how mechanical quantities and processes such as force, motion, and deformation influence food and the culinary arts. The aim of the course is to apply important aspects of mechanics to ideas in cooking. Specific topics include: (1) how do stress and strain affect food and its perceived taste; (2) what is the role of cell mechanics in the resulting micro structure of both consumed plant and animal tissues; (3) how can mechanics be used to alter nutrition; (4) what are the roles of common and uncommon mechanical tools such as a knife or mortar and pestle in food preparation. Emphasis will be placed on the biomechanics of edible matter across multiple length scales, including at the tissue, cellular, and molecular levels; additionally, impact on global health and engineering implications will be elucidated. During this course, we will introduce you to these concepts,train you to use them in real world applications, and allow you to pursue a creative group-defined project, which will be shared in both written and oral formats. We will integrate a hands-on kitchen experience in at least 3 specific laboratory classes so that students will get a true feel and understanding for culinary mechanics. We also will be visiting the restaurant of at least one first-rate Pittsburgh chef to gain real world insight into mechanics and cooking.

Course Website: http://www.cmu.edu/me/

24-370 Mechanical Design: Methods and Applications

Fall: 12 units
This is the third course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. Building on the principles and design methodology introduced in the first two courses, this course consists of a detailed study of typical loading conditions and resulting stresses and deflections in commonly used machine elements, such as shafts, gears, power screws, fasteners, brakes/couplings, flywheels, and bearings, and best practices in their design and application. Machine design against static and dynamic failure will be considered with focus on the effect of material properties, manufacturability, and cost considerations. Students will also learn the connections between theory and analytical methods, available computational tools, and field design. Learning objectives will be assessed through homework, class exams, and the conduct of the group projects.
Prerequisites: 24-200 and 24-262

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-371 Special Topics: Design of Machine Elements

Spring: 9 units
In this class, the students will gain an understanding of the best practices in the design of machine elements such as shafts, gears, power screws, fasteners, brakes/couplings, flywheels, bearings, etc. The course material consists of the study of stress and deflection under common loading conditions, effect of material properties, static and fatigue failure models, cost considerations, and manufacturability in the context of the machine components. Student learning will be achieved through interactive lectures on underlying technical approaches in conjunction with a group project where students will be required to design and fabricate an ensemble of machine elements. Students will also learn about the strong connections between theory, analytical methods, available computational tools, and field design. Assessment of the learning objectives will happen via homework, class exams, and demonstration of the group project. This course builds upon the skills and methods taught in Design-I (24-370) and will help students prepare to enter the modern workplace where mechanical design takes place.
Prerequisite: 24-370

24-381 Environmental Systems on a Changing Planet

Fall: 12 units
This course introduces the interconnected environmental systems that regulate our climate and ecosystems, providing the resources required to sustain all life, including human societies. We will explore how solar and biochemical energy moves through the Earths interconnected systems, recycling nutrients; how complex environmental systems function to produce critical resources such as food and water; and how human activities interfere with these systems. Earth science concepts will be used to explain the relationship between climate zones and biomes, the stability of the Earth's climate in the Holocene, and the instability in the current Anthropocene. Case studies include the interplay between climate change feedbacks, wildfires, ecosystems, and agricultural systems; the hazards that everyday chemical toxins pose to ecosystems and human health and reproduction; and growing threats to ecosystem health and biodiversity. We will also develop the relevant science and information literacy required to understand current issues that are frequently debated in the public sphere, and connect these to environmental justice. This course draws on principles learned in high school science and serves as the foundational Earth and amp; Environmental Science requirement for both the Minor and Additional Major in Environmental and Sustainability Studies.

24-390 Mechanical Engineering Co-op

Fall and Spring
The Department of Mechanical Engineering at Carnegie Mellon considers practical learning opportunities important educational options for its undergraduate students. One such option is cooperative education, which provides a student with an extended work experience with a company or government institution. To participate, students must possess at least junior status and have an overall grade point average of 3.0 or above. Students must complete a Co-Op Approval Form and submit it for approval. If the application is approved, the course will be added to the student's schedule and the student will be assessed tuition for 0 units for each semester that the student participates. All co-ops must be approximately 5-8 months in uninterrupted length. Upon completion of the co-op experience, students must submit a 1-2 page report of their work experience, and a 1-2 page evaluation from the company supervisor to the ME Undergraduate Education Committee. If the reports are approved, a "P" grade will be assigned. International students should contact their academic advisor for additional information. Prerequisite: Special permission required

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html (https://www.meche.engineering.cmu.edu/education/undergraduate-education/)

24-391 Mechanical Engineering Project

Fall and Spring
Practice in the organization, planning, and execution of appropriate engineering projects. These investigations may be assigned on an individual or a team basis and in most cases will involve experimental work.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html (https://www.meche.engineering.cmu.edu/education/undergraduate-education/)

24-392 Mechancial Engineering Project

All Semesters
Practice in the organization, planning, and execution of appropriate engineering projects. These investigations may be assigned on an individual or a team basis and in most cases will involve experimental work.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html (https://www.meche.engineering.cmu.edu/education/undergraduate-education/)

24-421 Internal Combustion Engines

Fall: 12 units
This course discusses working principles of internal combustion engines found in many practical applications. Focus is given to understanding the design of air handing system, in-cylinder fuel/air mixing, geometric design of the combustion chamber, engine performance and calibration, and mechanism of pollutant formation and reduction. Introductory discussion of advanced automotive engine concepts, alternative fuels, gas turbine engines, rocket engines, and hybrid electric vehicles is also provided. The course relies on a number of lab experiments, analysis of actual experimental data, and a combination of analytical and numerical homework assignments. 3 hrs. lecture 2 hrs. lab
Prerequisites: 24-221 and 24-231

Course Website: http://www.andrew.cmu.edu/user/satbirs/24421/

24-424 Energy and the Environment

Fall: 9 units
Fuel cycles for conventional and non-conventional energy resources; relationships between environmental impacts and the conversion or utilization of energy; measures of system and process efficiency; detailed study and analysis of coal-based energy systems including conventional and advanced power generation, synthetic fuels production, and industrial processes; technological options for multi-media (air, water, land) pollution control; mathematical modeling of energy-environmental interactions and tradeoffs and their dependency on technical and policy parameters; methodologies for energy and environmental forecasting; applications to issues of current interest. Junior or Senior standing in CIT or permission of instructor. 3 hrs lecture

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-425 Combustion and Air Pollution Control

Intermittent: 9 units
Formation and control of gaseous and particulate air pollutants in combustion systems. Basic principles of combustion, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, and flame structure. Formation of gaseous and particulate pollutants in combustion systems. Combustion modifications and post-combustion technologies for pollutant control. Relationship between technology and regional, national, and global air pollution control strategies. The internal combustion engine and coal-fired utility boiler are used as examples. 3 hours lecture Cross listed as 24-740 and 19440/19-740

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-428 Computational Analysis of Transport Phenomena

Spring: 9 units
In this course, students will develop basic understanding and skill sets to perform simulations of transport phenomena (mass, momentum, and energy transport) for engineering applications using a CAE tool, learn to analyze and compare simulation results with theory or available data, and develop ability to relate numerical predictions to behavior of governing equations and the underlying physical system. First 8 weeks of the course will include lectures and simulation-based homework assignments. During last 7 weeks, teams of students will work on self-proposed projects related to computational analysis of transport phenomena. In the project, students will learn to approach loosely defined problems through design of adequate computational mesh, choice of appropriate numerical scheme and boundary conditions, selection of suitable physical models, efficient utilization of available computational resources etc. Each team will communicate results of their project through multiple oral presentations and a final written report. Detailed syllabus of the course is provided on the URL given below.
Prerequisites: 24-322 and 24-221 and 24-231

Course Website: http://www.andrew.cmu.edu/user/satbirs/24618/

24-441 Product Design

Fall and Spring: 12 units
This course guides students through the design process in the applied design of a practical mechanical system. Lectures describe the typical design process and its associated activities, emphasizing methods for innovation and tools for design analysis. Professional and ethical responsibilities of designers, interactions with clients and other professionals, regulatory aspects, and public responsibility are discussed. The design project is typically completed in teams and is based on a level of engineering knowledge expected of seniors. Proof of practicality is required in the form of descriptive documentation. Frequently, a working model will also be required. Oral progress reports and a final written and oral report are required. 3 hrs. rec., 3 hrs lab Senior standing and Machine Shop Practice 24-200 required.
Prerequisites: 24-370 and 24-302

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-451 Feedback Control Systems

Fall: 12 units
Fundamentals of feedback control with emphasis on classical techniques and an introduction to discrete-time (computer controlled) systems. Topics include the following: frequency domain modeling and state space modeling of dynamical systems; feedback control system concepts and components; control system performance specifications such as stability, transient response, and steady state error; analytical and graphical methods for analysis and design - root locus, Bode plot, Nyquist criterion; design and implementation of proportional, proportional-derivative, proportional-integral-derivative, lead, lag, and lead-lag controllers. Extensive use of computer aided analysis and design software. 4 hrs lec.
Prerequisites: (15-112 or 15-110) and 24-352

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-452 Mechanical Systems Experimentation

Fall and Spring: 9 units
Experimentation in dynamic systems and controls. The course will cover translational and rotational systems. Topics will include mechanical elements, natural frequencies, mode shapes, free and forced response, frequency response and Bode plots, time constants, transient response specifications, feedback controls such as PID control, and stability for single-degree-of-freedom and multi-degree-freedom systems. The course will introduce and use state-of-the-art experimentation hardware and software.
Prerequisite: 24-352

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-453 Special Topics: Introduction to Programmable Logic Controllers

Fall and Spring: 3 units
Programmable Logic Controllers (PLCs) are prevalent in many industrial process control and manufacturing applications. Knowledge of and experience with PLCs is a marketable skill, opening up many career opportunities in a wide range of industries. This course provides an introduction to the applications of PLCs and techniques used for their programming and implementation. The course will be primarily lab-based, aimed at introducing the capabilities, limitations, and applications of PLCs through hands-on experience. Topics include ladder logic, PLC programming, PLC memory structures, program execution, troubleshooting methods, and typical industrial practices.
Prerequisite: 24-352

24-480 Special Topics: Artificial Intelligence and Machine Learning for Engineering

Spring: 9 units
This course introduces algorithms that are at the center of modern day artificial intelligence (AI) and machine learning (ML) techniques. The course takes an engineering-focused approach to AIML by investigating the wide array of sources of data available in the world, how these sources generate data, and algorithms and methods that are used to transform this data into knowledge/insights.
Prerequisites: (15-110 or 15-112) and (19-250 or 36-225 or 36-220 or 36-217)

24-491 Department Research Honors

Fall and Spring
This course is designed to give students increased exposure to "open-ended" problems and research type projects. It involves doing a project on a research or design topic and writing a thesis describing that project. The project would be conducted under the supervision of a mechanical engineering faculty member (the advisor), and must be approved by the advisor before inception. This course can be taken at any time after the Junior year and before graduation which includes the summer after the Junior year. Completion of 18 units of this course with a grade of B or better is a partial fulfillment of the requirements for Departmental Research Honors.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html (https://www.meche.engineering.cmu.edu/education/undergraduate-education/)

24-492 Department Research Honors

Fall and Spring
This course is designed to give students increased exposure to "open-ended" problems and research type projects. It involves doing a project on a research or design topic and writing a thesis describing that project. The project would be conducted under the supervision of a mechanical engineering faculty member (the advisor), and must be approved by the advisor before inception. This course can be taken at any time after the Junior year and before graduation which includes the summer after the Junior year. Completion of 18 units of this course with a grade of B or better is a partial fulfillment of the requirements for Departmental Research Honors.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html (https://www.meche.engineering.cmu.edu/education/undergraduate-education/)

24-602 Maker Series: Prototyping for Equity

Spring
This course applies prototyping techniques to develop products for underserved populations of people. In order to fabricate components for prototypes, this course teaches the safe operation of fabrication tools, including 3D printer, laser cutter-engraver machine, and power tools. A significant portion of the course is dedicated to applying the engineering design cycle to meet the unique needs/wants of a specific user population. This hands-on course culminates in building a prototype that can be tested to validate its performance as the physical solution to a real-world problem. 5-6-unit mini (7-weeks)

24-614 Microelectromechanical Systems

Intermittent: 12 units
This course introduces fabrication and design fundamentals for Microelectromechanical Systems (MEMS): on-chip sensor and actuator systems having micron-scale dimensions. Basic principles covered include microstructure fabrication, mechanics of silicon and thin-film materials, electrostatic force, capacitive motion detection, fluidic damping, piezoelectricity, piezoresistivity, and thermal micromechanics. Applications covered include pressure sensors, micromirror displays, accelerometers, and gas microsensors. Grades are based on exams and homework assignments.
Prerequisites: 18-321 or 24-351

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-623 Molecular Simulation of Materials

Spring: 12 units
The purpose of this course is to expose engineering students to the theory and implementation of numerical techniques for modeling atomic-level behavior. The main focus is on molecular dynamics and Monte Carlo simulations. Students will write their own simulation computer codes, and learn how to perform calculations in different thermodynamic ensembles. Consideration will be given to heat transfer, mass transfer, fluid mechanics, mechanics, and materials science applications. The course assumes some knowledge of thermodynamics and computer programming. 4 hrs lec.
Prerequisites: 24-311 and 24-221

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-626 Air Quality Engineering

Fall: 12 units
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.
Prerequisites: 24-231 and 36-220 and 09-105

Course Website: http://www.cmu.edu/me/

24-628 Energy Transport and Conversion at the Nanoscale

Spring: 12 units
Energy transport and conversion processes occur at the nanoscale due to interactions between molecules, electrons, phonons, and photons. Understanding these processes is critical to the design of heat transfer equipment, thermoelectric materials, electronics, light emitting diodes, and photovoltaics. The objective of this course is to describe the science that underlies these processes and to introduce the contemporary experimental and theoretical tools used to understand them. The course includes a laboratory that gives the students experience with modern transport measurement instrumentation and data analysis. Integrated literature reviews and a final project require students to apply learned fundamentals to understand state-of-the-art research and technology. 4 hrs. lecture
Prerequisites- 24-322 and amp; 24-221 or equivalents
Prerequisites: 24-322 and 24-221

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-629 Direct Solar and Thermal Energy Conversion

Intermittent: 12 units
This course introduces graduates and senior undergraduates the principles and technologies for directly converting heat and solar light into electricity using solid-state devices. The first part of the course reviews the fundamentals of quantum mechanics, solid state physics and semiconductor device physics for understanding solid-state energy conversion. The second part discusses the underlying principles of thermoelectric energy conversion, thermionic energy conversion, and photovoltaics. Various solar thermal technologies will be reviewed, followed by an introduction to the principles of solar thermophotovoltaics and solar thermoelectrics. Spectral control techniques which are critical for solar thermal systems will also be discussed. By applying the basic energy conversion theory and principles covered in lectures, students will finish a set of 4 homework assignments. This course also requires one project in which students will work individually to review one present solar or thermal energy conversion technology 12 units

Course Website: http://www.cmu.edu/me/

24-630 Advanced Thermal Engineering

Spring: 12 units
This course aims at advanced engineering analysis of thermal systems, while drawing upon the underlying principles of heat transfer. Lecture topics focus on the fundamentals of conduction, convection, radiation, and phase change, as they apply to practical thermal systems. The course activity includes lectures, individual homework assignments, lab activity, and team projects. The course plan assumes mastery of heat transfer at the undergraduate level (24-322 or equivalent).

24-632 Special Topics: Additive Manufacturing Processing and Product Development

Fall: 12 units
Introduction to additive manufacturing (AM) processing fundamentals and applications using Solidworks 3-D CAD software and a variety of polymer and metal AM machines. Includes a brief history of AM processing, a review of and technical fundamentals of current AM processes, a study of the current AM market, and future directions of the technology. Lab Sessions will support an open-ended product development project. Lectures on metals AM will address current research impacting industry. Students will also perform a literature review of papers on the state of the art. Basic Solidworks knowledge required.

Course Website: http://www.cmu.edu/me/

24-633 Additive Manufacturing Laboratory

Spring: 12 units
Hands-on laboratory projects will teach students about all aspects of metals additive manufacturing (AM). Students will learn how to use SOLIDWORKS for part design, create and transfer design files to the AM machines, run the machines to build parts, perform post-processing operations, and characterize AM parts. Students will work in teams and complete three separate lab projects, each utilizing a different material system, part design, AM process/machine, post-processing steps and characterization methods. A major lab report and presentation will be required for each of the three lab projects. The course includes weekly lectures to complement the laboratory component. Priority for enrollment will be given to students who have declared the Additive Manufacturing Minor.
Prerequisites: 24-632 or 27-765 or 27-503 or 39-601 or 39-602

24-634 Structural Design

Spring: 12 units
Design of structural members for bending moment, shear force, axial force, and combined axial force and bending. Reinforced concrete, structural steel, and composite beam construction are considered. Buckling effects in columns, beams and local plate segments are treated. Serviceability limits such as deflection and cracking are addressed. Design projects include the determination of loads and the selection of system geometry.

24-635 Structural Analysis

Fall: 12 units
Classical and matrix-based methods of structural analysis; energy principles in structural mechanics. Basic concepts of force and displacement methods for analyzing redundant structural systems. Matrix methods utilizing the flexibility (force) and stiffness (displacement) concepts.
Prerequisite: 24-262

24-636 Energy Applications in Biology and Medicine

Spring: 12 units
This course covers a wide range of energy-based applications in biology and medicine, such as cancer treatments by cryosurgery (freezing), thermal ablation (heating), photodynamic therapy (light-activated drugs), and irreversible electroporation (a non-thermal electrical application). This course also covers thermal regulation in humans and other mammals, as well as cryopreservation (low-temperature preservation) of tissues and organs for the benefit of organ banking and transplant medicine. The course combines lectures and individual assignments relating to the underlying principles of engineering, with teamwork on open-ended projects relating to concurrent challenges at the convergence of engineering and medical sciences. The course plan assumes a mastery of the fundamentals of heat transfer at the undergraduate level
Prerequisite: 24-322

24-637 Manufacturing Futures

Spring: 12 units
The course will introduce an array of technologies that will contribute to the future of making things and will be organized into 4 logical modules that will culminate in a team-based design project. Module 1 (Manufacturing Visions and Design Methodolgy): David Bourne. Module 2 (Manufacturing Processes and Process Tradeoffs): Brandon Bodily. Module 3 (Electronic Manufacturing): Rahul Panat. Module 4 (Workforce Development) : David Bourne.

24-638 Special Topics: Carbon Fiber Reinforced Polymers: Theory and Practice

Spring: 12 units
In terms of stiffness-to-weight and strength-to-weight ratios, carbon fiber reinforced polymer (CFRP) is a high performance structural material. It is widely used in the airline, sporting goods (bicycles, golf club shafts), energy (wind turbines), musical instruments, and medical prosthetic industries. CFRP is also used by civil engineers to enhance bridge strength and durability. This course will first briefly survey all types of composites (metal matrix, ceramic matrix, polymer matrix), and their application spaces. It will then discuss carbon fiber and polymer production methods, composite fabrication, and the associated enhancements in mechanical behavior of these materials in composite form. The method of digital image correlation (DIC), which enables full field strain measurements under applied stress, will be introduced, preceded by a discussion of optical imaging. A set of two laboratory exercises will involve fabricating specimens, characterizing them by DIC, and comparing stiffness and strength to various CFRP weaves. Students will develop expertise in CFRP design and analysis.

24-639 Special Topics: Thermal Systems Analysis and Design

Spring: 12 units
This course guides entry-level engineers through the design process of a thermal system. The course plan assumes a mastery of the fundamentals of fluid mechanics and heat transfer at the undergraduate level. Lecture topics include heat sinks, heat pipes, compact heat exchangers, sensors and instrumentation, thermoelectric devices, and special topics closely related to the theme of the design activity for the semester. Design activity is conducted in teams and includes several cycles of oral presentations, class discussions, and a final report writeup. System design and analysis of performance are based on computer-aided design tools and simulation means. Student performance in this course is evaluated based on individual homework assignments on the various topics presented in class and on a team design project.

24-640 Climate Change Mitigation

Intermittent: 12 units
Have you ever thought about how we could address the climate change problem? In this course we will study the technological and policy options for responding to the threat of climate change. We will review climate-change science, understand the current systems for energy supply and use, and have a deep dive onto technological solution for low-carbon energy supply and use, as well as the policy frameworks that can help us reduce greenhouse gas emissions. 2hrs 40min of lectures per week.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-643 Energy Storage Materials and Systems

Intermittent: 12 units
Contemporary energy needs require large scale electrochemical energy conversion and storage systems. Batteries are playing a prominent role in portable electronics and electric vehicles. This course introduces principles and mathematical models of electrochemical energy conversion and storage. Students will study thermodynamics, reaction kinetics pertaining to electrochemical reactions, phase transformations relating to batteries. This course includes applications to batteries, fuel cells, supercapacitors

Course Website: http://www.andrew.cmu.edu/user/venkatv/24643/

24-650 Applied Finite Element Analysis

Intermittent: 12 units
This is an introductory course on the finite element method with emphasis on application of the method to a wide variety of problems. The theory of finite element analysis is presented and students learn various applications of the method through assignments utilizing standard finite element software packages commonly used in industry. Various types of analyses are considered, which may include, for example, static, pseudo-static, dynamic, modal, buckling, contact, heat transfer, thermal stress and thermal shock. Students also learn to use a variety of element types in the models created, such as truss, beam, spring, solid, plate, and shell elements.

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html (https://www.meche.engineering.cmu.edu/education/graduate-programs/)

24-651 Material Selection for Mechanical Engineers

Spring: 12 units
This course provides a methodology for selecting materials for a given application. It aims to provide an overview of the different classes of materials (metal, ceramic, glass, polymer, elastomer or hybrid) and their properties including modulus, strength, ductility, toughness, thermal conductivity, and resistance to corrosion in various environments. Students will also learn how materials are processed and shaped (e.g., injection molding, casting, forging, extrusion, etc.), and will explore the origins of the properties, which vary by orders of magnitude. Topics include: Materials selection by stiffness, strength, fracture toughness and fatigue. Shape factors and materials processing. Binary phase and time temperature transformation diagrams, microstructure. Polymer types and structures. Alloying and strengthening of metals, types of steels. Corrosion, oxidation, tribology and thermal properties.
Prerequisites: 09-105 and 24-262

Course Website: http://www.cmu.edu/me/

24-652 Mechanical Behavior of Engineering Materials

Intermittent: 12 units
Mechanical engineers employ all classes of materials (metals, polymers, ceramics and hybrids) in load-bearing applications. To reduce material cost, save energy and maximize performance, engineering materials are frequently designed to be used near their load-bearing limits. An understanding of underlying deformation mechanisms complements a design rule approach in that "unexpected" failures can be far better anticipated and hence minimized. This course will survey the major deformation mechanisms in the main materials classes. Topics will include structure, elasticity, continuum failure models, fracture mechanics, and plastic deformation mechanisms of polymers, fiber-reinforced, composites, ceramics and metals. Proper design practice and real-life failures will be discussed.

Course Website: http://www.cmu.edu/me/

24-653 Special Topics: Materials and Their Processing for Mechanical Engineers

Spring: 12 units
The study of the major classes of materials (e.g., metals, alloys, ceramics, polymers, composites) and their structure-processing-property relationships is integral to many engineering disciplines. This course will introduce the fundamental concepts behind how the processing of materials influences their atomic/molecular structures and resulting properties. The course will adopt a game-based learning approach in which students will utilize the virtual Minecraft environment to study crystal structures, imperfections (defects), diffusion, and phase equilibria. These concepts are then applied to characterize and interpret the (mechanical, electrical, magnetic, and optical) properties of various material systems as part of a final collaborative group project.

24-654 Special Topics: Welding Engineering

Spring: 12 units
This course introduces the Welding Engineering field by teaching its fundamental aspects (e.g. metallurgy, solidification, heat transfer, arc physics, etc.) as applied to welding common ferrous and non ferrous materials with representative fusion (e.g. GMAW, LBW) and solid-state (e.g. FSW, FW) based processes and aspects of their use in production (i.e. variables to control, specific techniques and methodologies, standards/specifications, inspection and amp; testing of welds to ensure their quality). This will provide students with the knowledge to start to become more conversant in this discipline and to those that elect to further delve and specialize in specific areas of joining and amp; assembly, the preparation/step-stone to start to do so in their careers in industry or academia.

24-655 Cellular Biomechanics

Intermittent: 9 units
This course discusses how mechanical quantities and processes such as force, motion, and deformation influence cell behavior and function, with a focus on the connection between mechanics and biochemistry. Specific topics include: (1) the role of stresses in the cytoskeleton dynamics as related to cell growth, spreading, motility, and adhesion; (2) the generation of force and motion by moot molecules; (3) stretch-activated ion channels; (4) protein and DNA deformation; (5) mechanochemical coupling in signal transduction. If time permits, we will also cover protein trafficking and secretion and the effects of mechanical forces on gene expression. Emphasis is placed on the biomechanics issues at the cellular and molecular levels; their clinical and engineering implications are elucidated. 3 hrs. lec. Prerequisite: Instructor permission.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-656 Introduction to Vibrations with Applications

Spring: 12 units
This is an introductory course in vibrations and structural dynamics. Vibrations are frequently observed in mechanical (e.g., automobiles, robots), aerospace (e.g., airplanes, satellites), civil (e.g., buildings, bridges), and biological (e.g., eardrum, myocardial cells) systems. As such, modeling, analysis, experimentation, and control of vibrations are critical for many systems. This course covers fundamental concepts on vibrations of simplified (single- and multi-degree-of-freedom lumped-parameter models) and distributed-parameter systems (strings, beams in bending and torsion). Various applications of vibrations are analyzed. An overview of vibration testing and experimental modal analysis is also provided. The topics include free and forced response of single- and multi-degree of freedom structures; harmonic response analysis; vibration suppression; Lagrange's equations to derive the equations of motion; vibrations of strings and beams; and numerical methods to determine natural frequencies and mode shapes. Prerequisites: 24-352 and 24-351

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-658 Image-Based Computational Modeling and Analysis

Spring: 12 units
Image-based computational modeling and analysis play an important role in mathematical modeling and computer simulation of many physical and biological phenomena. This course integrates mechanical engineering, biomedical engineering, material sciences, computer science, and mathematics together. Topics to be studied include scanning techniques, image processing, geometric modeling, mesh generation, computational mechanics, as well as broad applications in biomedicine, material sciences and engineering. The techniques introduced are applied to examples of multi-scale modeling and simulations in various research fields.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-663 Special Topics: Biomechanics of Human Movement

Spring: 12 units
This course provides an overview of the mechanical principles underlying human movement biomechanics and the experimental and modeling techniques used to study it. Specific topics will include locomotion, motion capture systems, force plates, muscle mechanics, musculoskeletal modeling, three dimensional kinematics, inverse dynamics, forward dynamic simulations, and imaging-based biomechanics. Homework and final class projects will emphasize applications of movement biomechanics in orthopedics, rehabilitation, and sports. ***Students are expected to have knowledge of ordinary differential equations and rigid body dynamics at the level of 24-351.***

24-664 Introduction to Biomechanics

Fall: 12 units
The purpose of this course is to achieve a broad overview of the application of mechanics to the human body. This includes solid, fluid, and viscoelastic mechanics applied to single cells, the cardiovascular system, lungs, muscles, bones, and human movement. The physiology of each system will be reviewed as background prior to discussing mechanics applications within that system. There are no firm prerequisites, but statics, fluid mechanics, and biology are helpful.

Course Website: http://www.cmu.edu/me/

24-665 Special Topics: Wearable Health Technologies

Spring: 12 units
This project-based course will provide an overview of emerging wearable health technologies and give students hands-on experience in solving ongoing technical challenges. The wearable sensing field is experiencing explosive growth, with exciting applications in medicine. New lightweight devices will make it easier to monitor health conditions in real time, automatically import data into health informatics systems, and provide haptic feedback with humans in the loop. We will review several aspects of these technologies, including hardware, software and big data analytics, user experience, and applications. Students will be working collaboratively in a semester-long project that tackles timely experimental and computational challenges. Programing experience, in any language, is a pre-requisite.

Course Website: https://www.meche.engineering.cmu.edu/education/courses/24-665.html

24-666 Special Topics: Introduction to Geometric Dimensioning and Tolerancing

Spring: 3 units
Geometric Dimensioning and Tolerancing (GD and amp;T) encompasses a language and system of rules used to precisely and unambiguously communicate the intended geometry and allowable variation of manufactured objects. This tolerance informs the design, process selection, tooling, and inspection of a part. This course will introduce students to this system of communication and its applications. Topics will include interpreting GD and amp;T on engineering drawings, implementing it in Solidworks, and performing tolerance analyses.
Prerequisite: 24-370

24-667 Special Topics: Introduction to Geometric Dimensioning and Tolerancing

Spring: 6 units
Geometric Dimensioning and Tolerancing (GD and amp;T) encompasses a language and system of rules used to precisely and unambiguously communicate the intended geometry and allowable variation of manufactured objects. This tolerance informs the design, process selection, tooling, and inspection of a part. This course will introduce students to this system of communication and its applications. Topics will include interpreting GD and amp;T on engineering drawings, implementing it in Solidworks, and performing tolerance analyses.

24-668 Mechatronics Applications in Mechanical Engineering

Fall: 12 units
Most modern products contain elements of sensing, actuation, and control. This course builds on concepts from Dynamic Systems and Control to design simple mechatronic systems. Topics include modeling and selection of sensors and actuators, measurement systems, digital signal processing, microcontroller architectures, and the basics of state space control methods; these topics are taught in the context of integration with mechanical systems. This course includes a substantial project component in which students design, build, and test a mechatronic system through a series of subsystem prototypes and systems integration.

24-671 Electromechanical Systems Design

Fall: 12 units
This course guides students through the design process as applied to mechatronic systems, which feature electrical, mechanical, and computational components. Lectures describe the typical design process and its associated activities, emphasizing methods for analyzing and prototyping mechatronic systems. Professional and ethical responsibilities of designers, interactions with clients and other professionals, regulatory aspects, and public responsibility are discussed. The design project is team-based and is based on a level of engineering knowledge expected of seniors. Proof of practicality is required in the form of descriptive documentation and a working prototype system at the end of the course. Oral progress reports and a final written and oral report are required.

Course Website: http://www.cmu.edu/me/

24-672 Special Topics in DIY Design and Fabrication

Fall: 12 units
The traditional principles of mass production are being challenged by concepts of highly customized and personalized goods. A growing number of do-it-yourself (DIY) inventors, designers, makers, and entrepreneurs is accelerating this trend. This class offers students hands-on experience in DIY product design and fabrication processes. Over the course of the semester, students work individually or in small groups to design customized and personalized products of their own and build them using various DIY fabrication methods, including 3D laser scanning, 3D printing, laser cutting, molding, vacuum forming, etc. In addition to design and fabrication skills, the course teaches students skills for communicating their ideas effectively through industrial design sketches and presenting their products with aesthetically refined graphics.

Course Website: https://www.andrew.cmu.edu/course/24-672/

24-673 Soft Robots: Mechanics, Design and Modeling

Spring: 12 units
Soft, elastically-deformable machines and electronics will dramatically improve the functionality, versatility, and biological compatibility of future robotic systems. In contrast to conventional robots and machines, these ? soft robots? will be composed of elastomers, gels, fluids, gas, and other non-rigid matter. We will explore emerging paradigms in soft robotics and study their design principles using classical theories in solid mechanics, thermodynamics, and electrostatics. Specific topics include artificial muscles, peristaltic robotics, soft pneumatic robotics, fluid-embedded elastomers, and particle jamming. This course will include a final project in which students may work individually or as a team. For the project, students are expected to design and simulate and/or build all or part (eg. sensors, actuators, grippers, etc.) of a soft robot. Prerequisites: Statics and Stress Analysis or equivalents.

Course Website: http://www.cmu.edu/me/

24-677 Modern Control Theory

Fall: 12 units
This course offers a practical introduction to the analysis and design of model-based control for linear systems. Topics include modeling and linearization of multi-input multi-output dynamic systems using the state-variable description, fundamentals of linear algebra (linear space, linear transformation, linear dynamics), analytical and numerical solutions of systems of linear time-invariant differential and difference equations, structural properties of linear dynamic physical systems (controllability, observability and stability), canonical realizations, and design of state feedforward/feedback, optimal, and stochastic controllers and observers (pole placement, LQR, MPC, Kalman filter approaches). Students will learn how to design linear controllers and implement them to solve real-world problems in control and robotics.

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html (https://www.meche.engineering.cmu.edu/education/graduate-programs/)

24-680 Quantitative Entrepreneurship: Analysis for New Technology Commercialization

Intermittent: 12 units
This course provides engineers with a multidisciplinary mathematical foundation for integrated modeling of engineering design and enterprise planning decisions in an uncertain, competitive market. Topics include economics in product design, manufacturing and operations modeling and accounting, consumer choice modeling, survey design, conjoint analysis, decision-tree analysis, optimization, model integration and interpretation, and professional communication skills. Students will apply theory and methods to a team project for a new product or emerging technology, developing a business plan to defend technical and economic competitiveness. This course assumes fluency with basic calculus, linear algebra, and probability theory.

24-681 Computer-Aided Design

Intermittent: 12 units
his course is the first section of the two-semester sequence on computational engineering. Students will learn how computation and information technologies are rapidly changing the way engineering design is practiced in industry. The course covers the theories and applications of the measurement, representation, modeling, and simulation of three-dimensional geometric data used in the engineering designed process. Students taking this course are assumed to have knowledge of the first course in computer programming. 4 hrs lecture, 2 hrs computer cluster

Course Website: http://www.andrew.cmu.edu/course/24-681/

24-683 Design for Manufacture and the Environment

Fall: 12 units
Design for Manufacturing and the Environment examines influences of manufacturing and other traditionally downstream issues on the overall design process. Manufacturing is one facet that will be examined. Other downstream influences that will be studied include: assembly, robustness and quality, platform design, maintenance and safety, economics and costing, lean manufacturing and globalization. In addition, a core part of the course will focus on environment-based design issues. The class will study basic fundamentals in each of these areas and how they affect design decisions. Prerequisites: Senior standing in mechanical engineering, or permission of instructor

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-684 Special Topics: Nanoscale Manufacturing Using Structural DNA Nanotechnology

Fall: 12 units
This course provides an introduction to modern nanoscale manufacturing using structural DNAnanotechnology. This DNA-based approach to manufacturing has much in common with other fabrication methods in micro- and nano-engineering: computer aided design tools are necessary for device design and resulting structures can only be seen using advanced microscopy. However, instead of machining larger materials down to micro- and nanostructures, DNA origami is fabricated using a "bottom up" approach for self-assembling individual oligonucleotides into 2D and 3D nanostructures. Resulting structures can be designed to have novel mechanical and electrical properties and have applications as broad-ranging as medicine, biological computing, and energy systems. The course will include lectures, hands-on physical modeling, homework problems, 3D modeling of DNA origami using caDNAno and CANDO software, and student team projects and presentations.

Course Website: https://www.meche.engineering.cmu.edu/

24-685 Engineering Optimization without Project

Fall: 9 units
This course introduces students to 1) the process of formally representing an engineering design or decision-making problem as a mathematical problem and 2) the theory and numerical methods needed to understand and solve the mathematical problem. Theoretical topics focus on constrained nonlinear programming, including necessary and sufficient conditions for local and global optimality and numerical methods for solving nonlinear optimization problems. Additional topics such as linear programming, mixed integer programming, global optimization, and stochastic methods are briefly introduced. Model construction and interpretation are explored with metamodeling and model reformulation techniques, study of model boundedness, constraint activity, and sensitivity analysis. Matlab is used in homework assignments for visualization and algorithm development, and students apply theory and methods to a topic of interest in a course project. Fluency with multivariable calculus, linear algebra, and computer programming is expected. Students who are unfamiliar with Matlab are expected to learn independently using available tutorials and examples provided. This course is identical to 24-785 Engineering Optimization, except students in 24-685 will not complete the project, but will be responsible for any homework assignments and exams. 19785 and 24785: 12-units including the team-based engineering optimization project 19685 and 24685: 9-units excluding the project
Prerequisites: 21-259 and 21-341

Course Website: http://www.cmu.edu/me/

24-686 Advanced Mechanical Design

Intermittent: 12 units
This course will build expert foundational knowledge in mechanical design. Students will perform a series of multi-week modules in which they design, fabricate, and test high-performance mechanical components or assemblies individually or in small teams. Interactive lectures and topic readings on underlying technical approaches will occur simultaneously, thereby drawing a strong connection between theory, analytical methods, computational tools, and experience-based intuition. Modules will address optimal structures for tensile, bending, buckling, and torsion conditions, fatigue life, mechanism design, fluid power system design, and optimization of dynamical system properties. This course builds on the skills and methods taught in 24-370, Engineering Design I, and students are recommended to first take 24-370 and its prerequisites or similar courses at their undergraduate institution. Priority will be given to students who have already passed 24-200 Machine Shop Practice.
Prerequisite: 24-370

Course Website: http://www.cmu.edu/me (http://www.cmu.edu/me/)

24-687 Special Topics: New Technology Development and Roadmapping

Fall: 12 units
This course teaches a set of quantitative analysis methods fundamental to technology development and assessing the potential of emerging technologies. Students apply the analysis methods to a particular technology of their choosing in a project. The analysis tools learned in the course allow students to identify critical factors for advancing emerging technologies, strategizing R and amp;D to meet technical and market adoption targets, and predicting future technology performance. Topics include production models, adoption S-curves, dynamic consumer preferences, materials selection, and valuation of technological breakthroughs. Assignments include a series of presentations and written reports. The course assumes familiarity with college-level introductory probability and statistics.

Course Website: http://www.cmu.edu/me/

24-688 Introduction to CAD and CAE Tools

Fall: 12 units
This course offers the hands-on training on how to apply modern CAD and CAE software tools to engineering design, analysis and manufacturing. In the first section, students will learn through 7 hands-on projects how to model complex free-form 3D objects using commercial CAD tools. In the second section, students will learn through 7 hands-on projects how to simulate complex multi-physics phenomena using commercial CAE tools.
Units: 12 Format: 2 hrs. Lec., 2 hrs. computer lab

Course Website: http://www.cmu.edu/me/

24-691 Mechanical Engineering Project Management

Fall and Spring: 12 units
Organizations are increasingly adopting formal project management techniques to successfully initiate, plan, execute, monitor, control, and close out projects. In this course, students will learn project management tools which are commonly applied in industry. Working in teams, students will incorporate these tools into a documented plan for a project on which they are currently working or have previously completed. The project plan will address the ten knowledge areas of project management, including the management of project integration, scope, schedule, cost, quality, resources, communications, risk, procurement, and stakeholders. Students will also work in teams to plan and manage simulated projects. Real world constraints, challenges, and incentives will be applied. Additional special topics in project management will be discussed based on student interest, which may include lean, iterative, incremental, and industry-specific approaches, as well as productivity and human relations principles, and project management professional certification.

Course Website: http://www.cmu.edu/me/

24-692 Special Topics: Engineering a Startup: How to Start and Grow a Hardware Company

Fall: 12 units
Many modern devices are created by entrepreneurs starting their own enterprises. This course will provide a practical foundation for creating a new technology company. Specifically, it focuses on the unique challenges with creating, funding, and scaling a hardware-centric startup, with a heavy focus on examining real world examples of engineered product companies. Topics will include: issues with product development processes in a startup setting, identifying key market differentiators, launching a product to market, fund raising strategies, establishing and scaling manufacturing, and creating and understanding financial statements. This class is geared towards students with no business experience. The class will feature guest speakers with entrepreneurial experience developing and launching high tech products. The class will culminate with student teams creating and presenting an original pitch deck to a review board of entrepreneurs and investors.

Course Website: http://www.cmu.edu/me/

24-693 Special Topics: Leadership and Communication

Fall and Spring: 12 units
The objective of this course is to prepare students to be better leaders and communicators in their future careers, in industry, academia, and elsewhere. Topics include: psychological analysis of leaders and followers, negotiation and conflict resolution, interviewing, organizational decision making, and harnessing and deploying skills in challenging situations. To address these topics, the course employs new teaching techniques involving hands on activities, for example mock interviews and role playing around challenging situations. Learning outcomes include: improved ability to adapt, communicate, and lead in difficult situations in real time, understand team interactions and group dynamics to become a successful leader and follower, best practices in negotiating and resolving conflict in team situations and business interactions, and understand fundamentals of the interview process to achieve best outcomes.

24-695 Academic and Professional Development for Mechanical Engineering Masters Student

Fall: 1 unit
This course, required for all first-year masters students in the Department of Mechanical Engineering, will cover fundamental and practical topics for their academic and professional development. The course offers ten one-hour workshop sessions throughout the fall semester. A short assignment will be given after each session. The sessions will cover three categories of topics: (1) career planning, (2) graduate study, and (3) social issues. The first category covers alumni panels, Ph.D. panels, and employer information. The second category covers time management and group dynamics. The third category covers diversity, equity and inclusion, ethics, and academic integrity. Assessment Structure: Attendance and assignments

24-696 Professional Communication in Engineering

Fall and Spring: 5 units
This course, required for all masters students in the Department of Mechanical Engineering, will help students hone their written and oral communication skills for the workplace. Students will meet weekly throughout a semester to learn communication strategies, practice those strategies in formal and informal contexts, and give and receive peer feedback. There will be weekly deliverables (both written and oral) that will receive formal feedback from communication TAs. To maximize learning benefits, students will have the option to revise assignments in order to improve their skills. Topics covered include: preparing brief (30-60 second) pitches, responding to job interview questions, writing challenging emails, writing progress reports, writing executive summaries, presenting technical work to non-experts, writing project descriptions for non-experts, creating a web portfolio.

24-697 Research Communication in Mechanical Engineering

Spring: 4 units
This course, required for all MSME-R students, will support students in effectively writing and presenting their final research projects. Students will meet bi-weekly throughout a semester to learn communication strategies and give and receive peer feedback. There will be weekly deliverables (both written and oral) that will receive formal feedback from communication TAs. Topics covered include: writing a proposal, describing your project for different audiences, data visualization, designing a research poster, orally presenting your project in different venues, responding to questions about your project.
Prerequisites: 24-695 Min. grade C and 24-696 Min. grade C

24-703 Numerical Methods in Engineering

Fall: 12 units
This course covers numerical methods for solving a range of mathematical problems that are encountered in the analysis of engineering applications. Procedures will be presented for solving problems related to systems of equations, regression, optimization, integration, eigenvalues, ordinary differential equations, and partial differential equations. Students will be required to develop and implement computer algorithms and then apply them to engineering systems. Some programming experience is required.

Course Website: http://www.cmu.edu/me/graduate/courses.html

24-704 Probability and Estimation Methods for Engineering Systems

Fall: 12 units
Overview of rules of probability, random variables, probability distribution functions, and random processes. Techniques for estimating the parameters of probability models and related statistical inference. Application to the analysis and design of engineered systems under conditions of variability and uncertainty. 12 units Prerequisites(s) 26-211, or 36-220 or equivalent.
Cross listed CEE 12-704
Prerequisite: 36-220

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-711 Fluid Dynamics

Fall: 12 units
This course focuses on development and application of control volume forms of mass, momentum and energy conservation laws, differential forms of these laws in Eulerian and Lagrangian coordinates, and Navier-Stokes equations. Students also explore applications to problems in incompressible and compressible laminar flows, boundary layers, hydrodynamic lubrication, transient and periodic flows, thermal boundary layers, convective heat transfer, and aerodynamic heating. 4 hrs. lec. Prerequisites: 24-701 or permission of the instructor.
Prerequisite: 24-701

Course Website: https://www.meche.engineering.cmu.edu/

24-718 Computational Fluid Dynamics

Fall: 12 units
This course focuses on numerical techniques for solving partial differential equations including the full incompressible Navier-Stokes equations. Several spatial-temporal discretization methods will be taught, namely the finite difference method, finite volume method and briefly, the finite element method. Explicit and implicit approaches, in addition to methods to solve linear equations are employed to study fluid flows. A review of various finite difference methods which will be used to analyze elliptic, hyperbolic, and parabolic partial differential equations and the concepts of stability, consistency and convergence are presented at the beginning of the course to familiarize the students with general numerical methods. Detailed syllabus of the course is provided on the URL given below. 4 hr. lec
Prerequisites: 24-311 and 24-231

Course Website: http://www.andrew.cmu.edu/user/satbirs/24718/

24-721 Advanced Thermodynamics

Intermittent: 12 units
The course covers advanced macroscopic thermodynamics and introduces statistical thermodynamics. Review of first and second laws. Axiomatic formulation of macroscopic equilibrium thermodynamics and property relationships. Criteria for thermodynamic equilibrium with application to multiphase and multi-component systems. Thermodynamic stability of multiphase systems. Elementary kinetic theory of gases and evaluation of transport properties. Statistical-mechanical evaluation of thermodynamic properties of gases, liquids, and solids. Students are expected to have an undergraduate level of understanding of Thermodynamics (comparable to 24-221). 4 hrs. lec.
Prerequisite: 24-221

Course Website: http://www.andrew.cmu.edu/user/venkatv/24721/

24-722 Energy System Modeling

Fall: 12 units
This course focuses on the thermodynamic modeling of energy systems with emphasis on energy/availability analysis techniques. These techniques are developed and applied to both established and emerging energy technologies, such as internal combustion engines, gas- and coal-fired power plants, solar and wind energy systems, thermochemical hydrogen production cycles, and fuel cells. The course will also consider the integration of components such as reformers and electrolyzers. Modern computational tools are used throughout the course. The course culminates with a group project that requires developing sophisticated, quantitative models of an integrated energy system. Students are expected to have completed an undergraduate course in thermodynamics comparable to 24-221.
Prerequisites: 27-215 or 06-221 or 24-221

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-727 Special Topics: Aerosol Measurement Technology

Intermittent: 12 units
This course explores modern methods and instrumentation used to characterize key physical and chemical properties of aerosol particles, and the fundamental principles underlying the technology. Topics include particle sampling and collection (aerosol inlets, impactors, cyclones, virtual impactors, collection on substrates, electrostatic precipitation), aerosol charging and neutralization, particle size measurements (electrical mobility, optically, and aerodynamically based), particle detection (optical and electrical), aerosol optical properties, and the characterization of particle chemical composition (online mass spectrometry, in particular). Methods for analyzing both individual and ensembles of aerosol particles are discussed and compared. Recent advances reported in the literature are explored through student-led presentations. Students write a term paper describing and justifying their choice of techniques to solve a realistic aerosol measurement need. While the focus is on atmospheric aerosol particles, industrial applications such as particle synthesis and characterization are also discussed.

Course Website: http://www.cmu.edu/me/

24-730 Advanced Heat Transfer

Spring: 12 units
This course is open to students from all areas of engineering, although an undergraduate background in heat transfer is assumed. This class is an appropriate preparation for the doctoral qualifying exam.Topics to be covered include: mathematical formulation of heat transfer problems, heat conduction, thermal radiation, hydraulic boundary layers, and laminar and turbulent convection. Problems and examples will include theory and applications drawn from a spectrum of engineering design problems.
Prerequisite: Undergraduate Heat Transfer 24-322 or equivalent.
Prerequisite: 24-322

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-740 Combustion and Air Pollution Control

Intermittent: 12 units
24-740 Combustion and Air Pollution Control This course examines the generation and control of air pollution from combustion systems. The course's first part provides a brief treatment of combustion fundamentals, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, mass transfer, and flame structure. This foundation forms the basis for exploring the formation of gaseous (oxides of nitrogen, carbon monoxide, hydrocarbons, and sulfur dioxide) and particulate pollutants in combustion systems. The course then describes combustion modifications for pollutant control and theories for pollutant removal from effluent streams. The internal combustion engine and utility boilers serve as prototypical combustion systems for discussion. The course also addresses the relationship between technology and the formulation of rational regional, national, and global air pollution control strategies. Cross listed 19-740, 19-440, 24-425

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-751 Solid Mechanics and Elasticity

Fall: 12 units
This introductory course develops the fundamental concepts of continuum mechanics for solids in a manner useful for applications in engineering. Physical understanding of elasticity theory is introduced from first principles in kinematics, stress, and material constitutive laws with a focus on understanding and solving important problems in solids. Topics covered include linear elastic bodies; slender structures of rods and plates; finite deformation of rubbery materials; fracture and adhesion; contact mechanics; and dynamics. Emphasis is placed on using elasticity theory to not only solve classical problems but to also construct and understand experimental results and finite element method simulations in applied engineering applications and fundamental scientific research.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-753 Special Topics: Robotic Materials: Designs, Principles & Mechanics

Fall and Spring: 12 units
This is an interdisciplinary course focused on principles, theoretical models, and material architectures relevant to applications of condensed soft matter to problems in engineering. Special attention will be given to the design of soft, elastically-deformable machines and electronics that are primarily composed of elastomers, gels, fluids, gas, and other non-rigid matter. Specific topics will include the mechanics of hyperelastic solids, statistical mechanics of polymers and polymer composites, energy-based modeling techniques derived from the Laws of Thermodynamics, and their applications in modeling soft multifunctional material systems. Additionally, we will explore emerging paradigms in soft robotics, wearable computing, and human machine interaction, including material architectures for artificial muscles, stretchable electronics, and sensorized robotic skin. This course will include extensive reading with problem set assignments, a take-home exam, and final report. Students need familiarity with undergraduate-level solid mechanics, vector mechanics, thermodynamics, and ODEs
Prerequisite: 24-751

24-755 Finite Elements in Mechanics I

Fall: 12 units
The basic theory and applications of the finite element method in mechanics are presented. Development of the FEM as a Galerkin method for numerical solution of boundary value problems. Applications to second-order steady problems, including heat conduction, elasticity, convective transport, viscous flow and others. Introduction to advanced topics, including fourth-order equations, time dependence and nonlinear problems. 12 Units Prerequisite(s): Graduate standing or consent of instructor

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-760 Robot Dynamics and Analysis

Fall: 12 units
This course covers the dynamics of robotic systems with a focus on the mathematical structure of the dynamics and numerical analysis. Topics will start by reintroducing basic kinematics and dynamics in a more formal mathematical framework before moving on to contact conditions, friction, hybrid dynamical systems, simulation, and trajectory optimization. After the course students will be able to write simulation and optimization methods for analyzing robotic systems. Students should have taken a prior course in dynamics, and be comfortable with linear algebra, multivariable calculus, and programming in Matlab.
Prerequisites: 16-711 or 24-351

Course Website: http://www.andrew.cmu.edu/user/amj1/classes/robotdynamics.html

24-771 Linear Systems

Fall: 12 units
Topics include review of classical feedback control; solution of differential and difference equations; Laplace and Z-transforms, matrix algebra, and convolution; state variable modeling of dynamic continuous and discrete processes; linearization of nonlinear processes; state variable differential and difference equations; computer-aided analysis techniques for control system design; state variable control principles of controllability, observability, stability, and performance specifications; trade-offs between state variable and transfer function control engineering design techniques; and design problems chosen from chemical, electrical, and mechanical processes. 4 hrs. lec. Prerequisite: An undergraduate course in classical control engineering or consent of the instructor.
Prerequisite: 24-451

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-773 Multivariable Linear Control

Spring: 12 units
Robust control techniques are used in various industries, from hard disk drives to robotics, to rigorously account for model uncertainty and manufacturing variations. This course will introduce robust control of multi-input, multi-output linear systems, providing a synthesis of frequency-domain concepts from classical control with state space analysis from linear systems. Topics include performance limitations in control systems, uncertainty models, generalized plants, robust stability and performance measures, controller synthesis, and model order reduction. The course will mix theoretical developments with practical design examples drawn from industry (robotics, data storage, aerospace, etc.). This is intended to be the 2nd in a three course sequence designed to prepare students for an industrial career in control systems engineering.
Prerequisites: 24-771 Min. grade C or 24-677 Min. grade C

Course Website: http://www.cmu.edu/me/

24-774 Advanced Control Systems Integration

Fall: 12 units
This course focuses on the practical implementation of feedback / feedforward controllers. The entire controller design process is presented, including system modeling and identification, compensator design, simulation, and hardware prototyping. This is a project-based course in which students complete the controller design process on a nonlinear, MIMO hardware system. The goal is train students on the system integration skills necessary for success in industry or experimental laboratory work.
Prerequisites: 24-677 Min. grade C or 24-771 Min. grade C

Course Website: http://www.cmu.edu/me/

24-775 Bioinspired Robot Design and Experimentation

Spring: 12 units
This course will give students hands on experience designing, building, and analyzing robotic systems. Through a semester-long project, students will need to propose and test a research hypothesis with an experimental robotic system. Projects will focus on topics in bioinspired robotics and the robot must either test a biological hypothesis using a robot or test a hypothesis about the robot that is based on bioinspired robotic principles. In addition to the project, lectures and homework will cover topics in bioinspired robotics, robotic component design, systems integration, experimental instrumentation, biohybrid robotics, and biomimetic modeling. This class provides the opportunity for students to apply techniques in design, control, and analysis that students have acquired during their graduate studies. Students are expected to be comfortable programming in Matlab and have some prior graduate-level experience in mechanical design, controls, optimization, or robotics.

Course Website: https://www.andrew.cmu.edu/course/24-775/

24-776 Non Linear Control

Intermittent: 12 units
Nonlinear Control (12 Units) This course provides an introduction to the analysis and design of nonlinear systems and nonlinear control systems; stability analysis using Lyapunov, input-output and asymptotic methods; and design of stabilizing controllers using a variety of methods selected from linearization, vibrational control, sliding modes, feedback linearization and geometric control. 4 hrs. lec.
Prerequisite: 24-771

24-778 Mechatronic Design

Spring: 12 units
Mechatronics is the synergistic integration of mechanical mechanisms, electronics, and computer control to achieve a functional system. Because of the emphasis upon integration, this course will center around laboratory projects in which small teams of students will configure, design, and implement mechatronic systems. Lectures will complement the laboratory experience with operational principles and system design issues associated with the spectrum of mechanical, electrical, and microcontroller components. Class lectures will cover selected topics including mechatronic design methodologies, system modeling, mechanical components, sensor and I/O interfacing, motor control, and microcontroller basics.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-780 Engineering Computation

Fall: 12 units
This course covers the practical programming and computational skills necessary for engineers. These include: (1) programming in C++, (2) visualization using OpenGL, (3) basic data structures, and (4) basic algorithms. The course covers computational techniques required for solving common engineering problems and background algorithms and data structures used in modern Computer-Aided Design, Computer-Aided Manufacturing, and Computer-Aided Engineering tools. The course also offers intensive hands-on computational assignments for practice of common applications.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-781 Engineering Computation Project

Fall
24-781 This project course is the first section of the two-semester sequence of Computational Engineering Projects. The course provides the students with hands-on problem-solving experience by using commercial computational tools and/or developing their own custom software. Each student, individually or along with other students, will work on a project under the guidance of Carnegie Mellon faculty members and/or senior engineers from industry. Students may select a project topic from those presented by advising faculty members and/or industry engineers. Alternatively, a student may propose and work on his/her own project topic if he/she can identify a sponsoring faculty member or industry engineer.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-782 Machine Learning and Artificial Intelligence for Engineers - Project

Spring: 12 units
This course provides an open-ended computational project experience in artificial intelligence and machine learning. This course will enable student teams to design, develop and test data-driven computational algorithms. Course objectives are: - Gain experience in data sciences and data-driven methods for engineering. - Learn advanced programming and computational system design. - Learn project planning and management, project evaluation, teamwork, technical communication. The projects will target problems involving experimental, simulated or crowd-sourced data. Each project will aim to build an artificial intelligence or machine learning system that accomplishes one or more of the following: Identify patterns in data, establish a mathematical model for the input/output relationships, classify data into distinct categories, use existing data to synthesize new solutions to a synthesis problem. Team activities include three presentations, two written reports, a final technology demo, and one final report in the form of an archival publication.
Prerequisites: 15-781 Min. grade C or 10-601 Min. grade C or 24-787 Min. grade C or 10-701 Min. grade C

Course Website: http://www.cmu.edu/me/

24-783 Advanced Engineering Computation

Spring: 12 units
This course covers the advanced programming and computational skills necessary for solving engineering problems. These include (1) efficient data structures and algorithms for modeling and processing real-world data sets such as trees, hash tables, searching, priority queues, etc. (2) techniques for simulation and visualization such as numerically solving ODEs and PDEs, viewing control, programmable shader, etc., (4) tools for version controlling, scripting, and code building including sub-version, git, and cmake. Students will experience practical training in the above knowledge and programming skills through bi-weekly assignments and a final team project. Prerequisites- 24-780 Engineering Computation or equivalent C++ and OpenGL programming experience
Prerequisite: 24-780

Course Website: http://www.cmu.edu/me/

24-784 Special Topics: Trustworthy AI

Intermittent: 12 units
Innovations driven by recent progress in artificial intelligence such as deep learning and reinforcement learning, have shown human-competitive performance. However, as research expands to real-world cyber-physical autonomy, the question of safety is becoming a crux for the transition from theories to practice. This course will first review fundamental knowledge for trustworthy AI autonomy, including adversarial attack/defend, generative models, hierarchical Bayesian models, safe reinforcement learning, rare-event/few-shot learning, and robust evaluation. Then from the research perspective, students will explore the novelty and potential extension of various state-of-the-art trustworthy AI research and their implementation through a series of readings. Students will develop the ability to conduct research in teams. Knowledge and research skills learned in this course can be applied to self-driving, healthcare devices, assistant robots, and intelligent manufacturing. This course is devised for research-focused students who have backgrounds and interests in statistical machine learning, robotics and control, and human-machine interaction. Other interested students should contact the instructor to determine if it is a good fit for them.

24-785 Engineering Optimization

Intermittent: 12 units
Engineering Optimization Intermittent: 12 units This course introduces students to 1) the process of formally representing an engineering design or decision-making problem as a mathematical problem and 2) the theory and numerical methods needed to understand and solve the mathematical problem. Theoretical topics focus on constrained nonlinear programming, including necessary and sufficient conditions for local and global optimality and numerical methods for solving nonlinear optimization problems. Additional topics such as linear programming, mixed integer programming, global optimization, and stochastic methods are briefly introduced. Model construction and interpretation are explored with metamodeling and model reformulation techniques, study of model boundedness, constraint activity, and sensitivity analysis. Matlab is used in homework assignments for visualization and algorithm development, and students apply theory and methods to a topic of interest in a course project. Fluency with multivariable calculus, linear algebra, and computer programming is expected. Students who are unfamiliar with Matlab are expected to learn independently using available tutorials and examples provided. 4 hrs.lecture Prerequisites: None 19785 and 24785: 12-units including the team-based engineering optimization project 19685 and 24685: 9-units excluding the project
Prerequisites: 21-259 and 21-341

24-787 Machine Learning and Artificial Intelligence for Engineers

Fall: 12 units
This course introduces fundamental machine learning and artificial intelligence techniques useful for engineers working on data-intensive problems. Topics include: Probability and Bayesian learning, generative and discriminative classification methods, supervised and unsupervised learning, neural networks, support vector machines, clustering, dimensionality reduction, regression, optimization, evolutionary computation, and search. The lectures emphasize the theoretical foundations and the mathematical modeling of the introduced techniques, while bi-weekly homework assignments focus on the implementation and testing of the learned techniques in software. The assignments require knowledge of Python including text and image input/output, vector and matrix operations, simple loops, and data visualization. Students must have undergraduate level experience with linear algebra and vector calculus.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-788 Introduction to Deep Learning

Spring: 6 units
This course introduces the deep learning methodology. Students will learn about the basics of deep neural networks, and their applications to different tasks in engineering. Students will be able to apply Deep Learning to a variety of artificial intelligence tasks pertinent to different engineering problems. Neural Networks and Convolutional Neural Networks (CNN) and different variations of it will be taught. The fundamental knowledge and mathematics behind backpropagation and automatic differentiation will be discussed. Deep learning libraries such as Pytorch will be taught, and students will learn to use these libraries for developing deep learning models.
Prerequisites: 10-715 or 10-701 or 10-601 or 24-787 or 18-611

Course Website: http://www.cmu.edu/me/

24-789 Intermediate Deep Learning for Engineers

Spring: 6 units
This course will introduce some of the advances in deep learning technology such as sequential learning using Recurrent Neural Networks, Generative Adversarial Networks, Attention models and Transformers, and Diffusion models. Students will learn how to implement these models using deep learning libraries (Pytorch). Introduction to deep learning is the prerequisite.
Prerequisites: (11-785 or 10-601 or 10-715 or 24-787) and (11-785 or 24-788)

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-790 Thesis Research

Intermittent
This course is designed to give students enrolled in the Ph.D. program an opportunity to conduct extensive research over the course of their studies. Variable hrs.

24-791 Graduate Seminar

All Semesters
Graduate seminar speakers include faculty, students, and invited guests from industry and academia. Through seminars, students widen their perspectives and become more aware of other topics in mechanical engineering

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-793 Supervised Reading

Fall and Spring
This independent study is designed to give students an opportunity to explore pertinent subjects through faculty directed reading. Variable hrs. Prerequisite: Completion of "Supervised Reading" form acquired by your graduate MechE advisor; which includes permission of the instructor.

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html (https://www.meche.engineering.cmu.edu/education/graduate-programs/)

24-794 Master of Science Research

Fall and Spring
This course is designed to be a training opportunity in engineering research and associated professional activity. Content includes a series of investigations under the student's initiative culminating in comprehensive reports, with special emphasis on orderly presentation and effective English composition for Master of Science candidates. Variable hrs. Prerequisite: permission of the instructor.

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html (https://www.meche.engineering.cmu.edu/education/graduate-programs/)

24-795 PhD Internship in Teaching Counterpoint

Fall and Spring
A teaching assignment under the guidance of a faculty member for intermediate or terminal-level doctoral candidates. Typical activities include preparing and teaching recitations, preparing and teaching laboratory sessions, holding office hours, grading and preparation of quizzes, problem sets and other assignments, and assisting instructor with other activities associated with teaching a course. 24-795 is 12 units and offered in Fall and Spring (P/F). All non-native English speakers must conform to the university regulation on the TA language requirements.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-797 Thesis Research

Fall and Spring
This course is designed to give students enrolled in the Ph.D. program an opportunity to conduct extensive research over the course of their studies. Variable hrs.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-799 Practicum in Mechanical Engineering

All Semesters
The Department of Mechanical Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its graduate students. One such option is an internship, normally completed during the summer. If a student receives an internship, the Mechanical Engineering Department will add the internship course to the student's schedule, and the student will be assessed tuition for 3 units. Upon completion of the internship, students must submit a 2-3 page report with supervisor signature detailing the work experience and including how the internship was related to Mechanical Engineering. After the report has been reviewed and approved, a letter grade will be assigned and these 3 units will count towards degree requirements. International students interested in registering for the practicum must also be authorized for Curricular Practical Training (CPT). Further information is available on the Office of International Education?s website: www.cmu.edu/oie.

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html (https://www.meche.engineering.cmu.edu/education/graduate-programs/)

24-850 Implantable Cell-Based Medical Devices

Fall: 12 units
This advanced seminar course explores the emerging field of implantable medical devices that utilize living cells to deliver therapeutics and/or continuously monitor patient's health through key biomarkers. After discussing requirements for such devices, the course will examine the literature on various aspects, including design principles, material requirements, cell engineering and selection, cell encapsulation and protection, supporting long-term cell viability and functionality in vivo. We will then discuss various current and emerging applications of those devices from targeted drug delivery for various diseases to continuous biomarker monitoring enabling personalized treatment strategies. We will conclude by examining the regulatory pathways and clinical trials necessary to bring these groundbreaking devices to patients.

24-892 Locomotion Seminar

Intermittent
The CMU Bipedal Locomotion Seminar is a weekly meeting amongst students and professors who study bipedal locomotion using a variety of approaches. Each week, one graduate student participant gives a presentation on a topic of their choosing related to their research. We encourage discussion and interaction, especially from fellow students. Each meeting is intended to work like a small, informal conference discussion or workshop, providing students with new perspectives on their projects, practice presenting and answering questions, and a forum for meeting colleagues. We encourage participation from all interested students and faculty, including members of Carnegie Mellon, The University of Pittsburgh, and Disney Research Pittsburgh. Please join the waitlist and contact one of the instructors for admission.

Course Website: http://www.andrew.cmu.edu/user/amj1/locomotion_seminar.html

24-991 Professional Development for PhD students

Fall: 2 units
This course is the first in a sequence of two required courses where incoming PhD students learn research and professional communication skills that will benefit them throughout the PhD and in their careers. Topics covered include DEI and cross-cultural communication, reading and understanding technical publications, building the student/advisor relationship, working in teams, communicating by email, presenting for success, receiving and addressing critical feedback, and performing a literature review. The class intends to strengthen the PhD cohort and activities will often require group work and evaluation.

24-992 Professional Development for PhD students II

Spring: 2 units
This is one of two required courses (the other being 24-991) where incoming PhD students learn research and professional skills that will benefit them throughout the PhD and in their careers. Topics covered include leadership and equity in teamwork, equity in evaluation, ethics in research, presenting your work to different audiences, responding to questions in an oral presentation, responding to peer review, and writing an effective abstract. The class intends to strengthen the PhD cohort and activities will often require group work and evaluation. Students entering in the Spring should take 24-992 before 24-991