BIOMEDICAL ENGINEERING (B M E)

B M E 1 – COOPERATIVE EDUCATION PROGRAM
1 credit.

Work experience which combines classroom theory with practical knowledge of operations providing a background upon which to base a professional career in industry.
Requisites: Sophomore standing
Course Designation: Workplace - Workplace Experience Course
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Identify and respond appropriately to real-life engineering ethics cases relevant to co-op work
Audience: Undergraduate

2. Synthesize and apply appropriate technical education to real world technical work
Audience: Undergraduate

3. Communicate effectively in writing and speaking with a range of audiences in the workplace, including those without disciplinary expertise
Audience: Undergraduate

4. Develop professional and transferable habits like time management skills, collaborative problem-solving skills, and research skills for learning new information
Audience: Undergraduate

B M E 200 – BIOMEDICAL ENGINEERING DESIGN
2 credits.

Collaborate with students in B M E 300 on a client-centered biomedical engineering design project to learn concept generation, product analysis, specifications, evaluation, regulation, and ethics.
Requisites: Sophomore standing and declared in Biomedical Engineering
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences
Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies
Audience: Undergraduate

B M E 201 – BIOMEDICAL ENGINEERING DESIGN AND FUNDAMENTALS
3 credits.

Fundamentals of biomedical engineering and principles of design including the design process, standards, documentation, inclusion in design and research methods. Hands-on skills including electronics, programming, computer-aided design, machining, safety training, microscopy, cell and tissue engineering principles and fabrication of physical prototypes.
Requisites: B M E 200
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences
Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies
Audience: Undergraduate

B M E 300 – BIOMEDICAL ENGINEERING DESIGN AND LEADERSHIP
3 credits.

Work on a client-centered biomedical engineering design project to learn leadership styles, concept generation, product analysis, specifications, evaluation, regulation, and ethics. Provide leadership and mentorship to students in B M E 200.
Requisites: B M E 201
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences
Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies
Audience: Undergraduate

B M E 301 – BIOMEDICAL ENGINEERING DESIGN AND COMMUNICATION
3 credits.

Technical communication for biomedical engineering practice applied to real-world, client-based projects including research methods, documentation, preparing and critiquing reports, ethical problem solving, diversity and inclusion, presenting, and professional development.
Requisites: Satisfied Communications A requirement and B M E 201
Course Designation: Gen Ed - Communication Part B
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
Audience: Undergraduate

3. share research, design ideas, testing plans and results in writing and in presentations to both peers and professionals
Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies
Audience: Undergraduate

8. identify and make skillful use of relevant, reliable, and high-quality research sources appropriate for the design project
Audience: Undergraduate

9. make productive use of the writing process, including brainstorming, outlining, drafting, incorporating feedback, and revising, to develop a fledgling idea into a formal paper, presentation, and project
Audience: Undergraduate

10. make use of expressive conventions and protocols (e.g., organization, content, presentation, formatting) consistent with technical communication
Audience: Undergraduate

B M E 310 – BIOINSTRUMENTATION
3 credits.

Bioinstrumentation covering clinical and research measurements. Laboratory experiments complement the lectures.
Requisites: (CHEM 104, 109, or 116), MATH 222, and (PHYSICS 202, 208, or 248), or member of Engineering Guest Students
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Solve mathematical problems for electrical and electronic circuits
Audience: Undergraduate

2. Employ simulation tools to analyze electrical and electronic circuits
Audience: Undergraduate

3. Design and build basic instrumentation system for measuring physiological and biological signals
Audience: Undergraduate

4. Program a microcontroller to acquire and process physiological and biological signals
Audience: Undergraduate

5. Perform experiments using the instrumentation system, analyze data and draw conclusions
Audience: Undergraduate

B M E 315 – BIOMECHANICS
3 credits.

An introduction to the mechanical behavior of biological tissues and systems. Specific topics include: structure and function of biological tissues, mechanical properties of biological tissues, and analysis of specific tissues (i.e. bone, muscle, and soft connective tissues).
Requisites: (E M A 303 or M E 306), or member of Engineering Guest Students
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Apply mechanical equilibrium analyses to compute forces acting on tissues, organs and structures within the human body
Audience: Undergraduate

2. Examine mechanical stress and deformation associated with the loading of biological tissues
Audience: Undergraduate

3. Analyze, interpret and present data collected during experiments in biomechanics
Audience: Undergraduate

4. Describe the relevance of mechanics for investigating biological systems at scales ranging from cellular to the whole body
Audience: Undergraduate

B M E 325 – APPLIED STATISTICS FOR BIOMEDICAL ENGINEERS
3 credits.

Learn and apply the fundamentals of descriptive and inferential statistics to analyze data and present the results in appropriate graphical formats. Emphasis will be on applications commonly encountered in biomedical engineering including t-tests, linear regression, analysis of variance, diagnostic tests, ROC curves, and methods for graphing and presenting data. Examples and practice problems will be drawn from biomedical research. Learn how to analyze data and interpret statistical analysis presented in research papers, and will get practical hands-on experience implementing these tools during class in a computer lab setting.
Requisites: Declared in Biomedical Engineering and MATH 222
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. interpret statistics that are presented and recognize statistical evidence that supports a conclusion
Audience: Undergraduate

2. apply descriptive statistical analysis to data
Audience: Undergraduate

3. make inferences based on sampled data (test a hypothesis)
Audience: Undergraduate

4. present data and statistical analysis in appropriate graphical format
Audience: Undergraduate

B M E 330 – ENGINEERING PRINCIPLES OF MOLECULES, CELLS, AND TISSUES
4 credits.

Introduction to the fundamental principles of kinetics and transport that are relevant for the analysis of biological systems. Topics covered include concepts of reaction rate, stoichiometry, equilibrium, momentum/mass transport, and the interaction between transport and kinetics in biological systems.
Requisites: (E M A 201, PHYSICS 201, 207, or 247), (MATH 319, 320, or 375) and (CHEM 104, 109, or 116), or member of Engineering Guest Students
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Assess the relationship between system variables based on dimensional homogeneity and dimensional analysis
Audience: Undergraduate

2. Convert a reaction system into a series of kinetic equations
Audience: Undergraduate

3. Recognize the parallels between different transport mechanisms
Audience: Undergraduate

4. Analyze kinetic and transport equations to determine dynamic and steady state behavior
Audience: Undergraduate

5. Evaluate how the physical principles of kinetics and transport constrain living organisms and impact the design and interpretation of biological experiments
Audience: Undergraduate

B M E 389 – HONORS IN RESEARCH
1-3 credits.

Undergraduate honors research projects supervised by faculty members.
Requisites: Consent of instructor
Course Designation: Honors - Honors Only Courses (H)
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Conduct and report on independent biomedical engineering research
Audience: Undergraduate

2. Formulate hypotheses into experimental methods
Audience: Undergraduate

B M E 399 – INDEPENDENT STUDY
1-3 credits.

Directed study projects as arranged with instructor.
Requisites: Consent of instructor
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Conduct and report on independent biomedical engineering research
Audience: Undergraduate

B M E 400 – CAPSTONE DESIGN COURSE IN BIOMEDICAL ENGINEERING
3 credits.

Applies classroom study and prior design course experiences for senior teams to solve a directed client-based biomedical engineering design project.
Requisites: (B M E 300 or B M E 301) and (B M E 310, 315, or PHM SCI/ B M E 430)
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences
Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies
Audience: Undergraduate

B M E 402 – BIOMEDICAL ENGINEERING CAPSTONE DESIGN II
3 credits.

Work in a team to evaluate, refine, document and present the client-centered biomedical engineering design started in B M E 400.
Requisites: B M E 400
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
Audience: Undergraduate

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
Audience: Undergraduate

3. an ability to communicate effectively with a range of audiences
Audience: Undergraduate

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
Audience: Undergraduate

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
Audience: Undergraduate

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
Audience: Undergraduate

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies
Audience: Undergraduate

B M E/M E 414 – ORTHOPAEDIC BIOMECHANICS - DESIGN OF ORTHOPAEDIC IMPLANTS
3 credits.

Apply the design process for orthopaedic implants (total joint replacements). Topics include: library skills; joint anatomy; tissue properties; surgical approach; joint loading; implants materials; preclinical testing and analysis.
Requisites: Senior standing and M E 342, graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Apply engineering mechanics (statics, dynamics, mechanics of materials) to analyze human joints
Audience: Both Grad & Undergrad

2. Describe sources and implications of patient-to-patient variability in functional anatomy, biomechanics, and disease states
Audience: Both Grad & Undergrad

3. Synthesize knowledge about functional anatomy, biomechanics, and disease states to define clinical needs and design inputs
Audience: Both Grad & Undergrad

4. Justify design decisions and testing plans based on rigorous engineering calculations through both written and oral communication
Audience: Both Grad & Undergrad

5. Formulate rigorous testing plans for design and device verification and validation based on established standards and/or guidance documents
Audience: Both Grad & Undergrad

6. Analyze interactions between multiple sources of variability
Audience: Graduate

B M E/M E 415 – BIOMECHANICS OF HUMAN MOVEMENT
3 credits.

An overview of experimental and modeling techniques used to study human movement. Specific topics will include locomotion, motion capture systems, force plates, muscle mechanics, musculoskeletal modeling, three dimensional kinematics, inverse dynamics, forward dynamic simulation and imaging based biomechanics. Homework and laboratory activities emphasize applications of movement biomechanics in orthopedics and rehabilitation.
Requisites: B M E 315 and M E 340, graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Identify and describe fundamental concepts and methods in movement biomechanics
Audience: Both Grad & Undergrad

2. Apply fundamental concepts and methods in biomechanics to acquire experience and gain confidence using engineering tools to study movement
Audience: Both Grad & Undergrad

3. Establish a framework for self-teaching and research through open-ended laboratory assignments and a research project
Audience: Both Grad & Undergrad

4. Constructively review and provide feedback on written research proposals related to movement biomechanics
Audience: Graduate

B M E/PHM SCI 430 – BIOLOGICAL INTERACTIONS WITH MATERIALS
3 credits.

Addresses the biological systems governing biomaterial applications, a select range of materials currently being utilized for various biomedical applications, analytical techniques pertinent to biomaterial evaluation, and select major medical applications in which biomaterials play an important role.
Requisites: (ZOOLOGY/BIOLOGY 101 and 102, ZOOLOGY/BIOLOGY/BOTANY 151, ZOOLOGY 153, or BIOCORE 383) and (CHEM 341 or 343), or graduate/professional standing
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Integrate biology, material science, and engineering
Audience: Undergraduate

2. Evaluate the design of materials for specific biomedical applications
Audience: Undergraduate

3. Formulate experimental designs and demonstrate data analyses to assess biological responses to materials
Audience: Undergraduate

4. Describe the clinical utility and limitations of various materials for specific biomedical applications
Audience: Undergraduate

5. Demonstrate practical understanding of biomaterial-based laboratory safety and techniques
Audience: Undergraduate

B M E/E C E 462 – MEDICAL INSTRUMENTATION
3 credits.

Design and application of electrodes, biopotential amplifiers, biosensors, therapeutic devices. Medical imaging. Electrical safety. Measurement of ventilation, blood pressure and flow.
Requisites: E C E 340, graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Solve complicated mathematical problems for electrical and electronic circuits
Audience: Both Grad & Undergrad

2. Employ simulation tools to test and analyze electronic circuits for measuring physiological signals
Audience: Both Grad & Undergrad

3. Design electronic schematics for advanced instrumentation system using software tools
Audience: Both Grad & Undergrad

4. Solder and build advanced instrumentation system for measuring physiological signals
Audience: Both Grad & Undergrad

5. Program a microcontroller to acquire and process physiological signals
Audience: Both Grad & Undergrad

6. Perform experiments using the instrumentation system, analyze data and draw conclusions
Audience: Both Grad & Undergrad

7. Demonstrate an ability to formulate, analyze and, independently design and build instrumentation system to measure physiological signals
Audience: Graduate

B M E/E C E 463 – COMPUTERS IN MEDICINE
3 credits.

Study of microprocessor-based medical instrumentation. Emphasis on real-time analysis of electrocardiograms. Labs and programming project involve design of biomedical digital signal processing algorithms. Knowledge of computer programming language like C, C++ or Java, strongly encouraged.
Requisites: E C E 330 and (COMP SCI 200, 220, 300, 301, or placement into COMP SCI 300), graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Solve complicated mathematical problems with design of digital filters for biomedical signals
Audience: Both Grad & Undergrad

2. Build electrocardiogram (ECG) instrumentation system to view their ECG and use it as an input to a microcontroller for signal analysis
Audience: Both Grad & Undergrad

3. Employ simulation tools to design and test a variety of linear digital filters
Audience: Both Grad & Undergrad

4. Perform experiments, analyze and interpret the performance of digital filters on a database of ECGs
Audience: Both Grad & Undergrad

5. Write microcontroller code for real-time processing of biomedical signals, particularly the ECG, to attenuate diverse noise sources and find clinically-significant features
Audience: Both Grad & Undergrad

6. Demonstrate an ability to formulate and, independently design and implement digital filters and algorithm to process biomedical signals
Audience: Graduate

B M E 489 – HONORS IN RESEARCH
1-3 credits.

Biomedical engineering undergraduate honors research projects supervised by faculty members.
Requisites: Consent of instructor
Course Designation: Honors - Honors Only Courses (H)
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Conduct and report on independent biomedical engineering research
Audience: Undergraduate

2. Formulate hypotheses into experimental methods
Audience: Undergraduate

3. Prepare and defend experimental results and conclusions
Audience: Undergraduate

B M E/H ONCOL/MED PHYS/PHYSICS 501 – RADIATION PHYSICS AND DOSIMETRY
3 credits.

Interactions and energy deposition by ionizing radiation in matter; concepts, quantities and units in radiological physics; principles and methods of radiation dosimetry.
Requisites: (PHYSICS 323, 449 and MATH 320) or graduate/professional standing or declared in Medical Physics VISP
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Use the physics of microscopic structures of nucleus, nuclear decay, electronic structure of atoms to calculate nuclear decay lifespan and solid state energy band structure
Audience: Both Grad & Undergrad

2. Calculate the radiation power spectrum for an accelerating charge particle under different physical conditions
Audience: Both Grad & Undergrad

3. Calculate cross-sections for the following interaction processes between photons and matter: Rayleigh scattering, photoelectric effect, Compton scattering, and pair production
Audience: Both Grad & Undergrad

4. Calculate the scattering cross-section of Coulomb scattering and energy transfer cross-section in collisions processes and radiative energy loss processes
Audience: Both Grad & Undergrad

5. Calculate radiation dose for both external photon beams, neutron beams, and charged particle beams
Audience: Both Grad & Undergrad

6. Identify open research topics in radiation imaging, radiation therapy, and radiation protection fields
Audience: Graduate

B M E/M E 505 – BIOFLUIDICS
3 credits.

Introduction to the physics of biological fluid flow with an emphasis on the cardiovascular system including blood rheology, pulsatile flow, wave travel, and topics relevant to blood flow measurement and biomedical device design.
Requisites: B M E 330, CBE 320, M E 363, graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Explain the physical properties of a fluid and the consequence of such properties on fluid flow; compare and contrast non-Newtonian models for blood rheology
Audience: Both Grad & Undergrad

2. State the conservation principles of mass, linear momentum, and energy for fluid flow
Audience: Both Grad & Undergrad

3. Analyze systems using the conservation equations
Audience: Both Grad & Undergrad

4. Identify the relevant parameters that govern a fluid system and use dimensional analysis to identify the fundamental variables that define flow
Audience: Both Grad & Undergrad

5. Describe the flow dynamic metrics in different physiological or pathological conditions
Audience: Both Grad & Undergrad

6. Identify the role of other professionals in biofluid mechanics
Audience: Graduate

7. Foster skills to interact with clinical professionals
Audience: Graduate

B M E 510 – INTRODUCTION TO TISSUE ENGINEERING
3 credits.

Overview of tissue engineering, including discussion of cell sources, cell-material interactions, tailoring biomaterials, methods of culture and characterization of engineering tissues, ethical issues, concluding with case studies of specific types of tissue engineering. Optional laboratory exercises offered throughout semester.
Requisites: B M E/PHM SCI 430, graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Identify the experimental assay that is appropriate to characterize a particular cellular behavior
Audience: Both Grad & Undergrad

2. Describe how to tailor mechanical properties, cell-material interactions, growth factor/gene delivery, and bioreactor conditions to match the needs of a biological system
Audience: Both Grad & Undergrad

3. Critically evaluate tissue engineering approaches
Audience: Both Grad & Undergrad

4. Assess a biological system and develop a tissue engineering strategy
Audience: Both Grad & Undergrad

5. Summarize and synthesize recent tissue engineering related research from various resources
Audience: Graduate

B M E 511 – TISSUE ENGINEERING LABORATORY
1 credit.

Tissue engineering refers to the generation of biological substitutes to restore, maintain, or improve tissue function. Laboratory techniques are multi-disciplinary, from basic biological sciences, engineering, and biotechnology. Engineering approaches and analysis will be applied to these techniques.
Requisites: B M E 510 or concurrent enrollment, or graduate/professional standing
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Identify and describe the biology of, growth conditions for and laboratory equipment used in tissue culture
Audience: Undergraduate

2. Design and conduct laboratory experiments, including making measurements and interpreting experimental data from living systems
Audience: Undergraduate

3. Apply knowledge of advanced mathematics and statistical analysis to evaluate scientific outcomes
Audience: Undergraduate

4. Communicate scientific findings from experimental results effectively
Audience: Undergraduate

B M E/M E 516 – FINITE ELEMENTS FOR BIOLOGICAL AND OTHER SOFT MATERIALS
3 credits.

Finite element modeling of soft materials, with an emphasis on biological tissues. Basics of the finite element method, verification and validation methods, and selection of constitutive models. Emphasis on finite element modeling for materials that are generally nonlinear, and that generally undergo large deformation.
Requisites: (M E 306 or E M A 303), graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Define the finite element method, explain its mathematical basis, and articulate alternatives
Audience: Both Grad & Undergrad

2. Justify the selection of a constitutive model for a particular modeling application
Audience: Both Grad & Undergrad

3. Design and complete validation and verification analyses
Audience: Both Grad & Undergrad

4. Build and analyze a finite element model, and present relevant results
Audience: Both Grad & Undergrad

5. Complete a term project using finite element analysis individually
Audience: Graduate

B M E 517 – BIOLOGY IN ENGINEERING SEMINAR
1 credit.

Current topics at the interface of biology and engineering with special emphasis on the ways in which engineers have contributed to knowledge and advances in biology.
Requisites: (ZOOLOGY/BIOLOGY 101 and 102, ZOOLOGY/BIOLOGY/BOTANY 151, ZOOLOGY 153, or BIOCORE 381), graduate/professional standing, or member of Engineering Guest Students
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Identify and describe a wide variety of engineering approaches that have advanced our understanding of biology
Audience: Undergraduate

2. Assimilate presented topics with relevant literature into writing
Audience: Undergraduate

B M E 520 – STEM CELL BIOENGINEERING
3 credits.

Covers engineering approaches that are used to understand and manipulate stem cells. Concepts covered include: introduction to stem cell biology, quantitative modeling of stem cell signaling, methods to engineer the stem cell microenvironment, and the role of stem cells in tissue development and regeneration.
Requisites: (MATH 319 or 320), (ZOOLOGY 470, 570, or BIOCORE 383), and (CHEM 341 or 343), graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Describe the historical development and current state of stem cell engineering
Audience: Both Grad & Undergrad

2. Model stem cell signaling
Audience: Both Grad & Undergrad

3. Characterize the technical features and functions of stem cell therapy
Audience: Both Grad & Undergrad

4. Evaluate stem cell-based tissue development and regeneration
Audience: Both Grad & Undergrad

5. Demonstrate higher-order synthesis and analysis to address a current problem in stem cell bioengineering
Audience: Graduate

B M E/MED PHYS 535 – INTRODUCTION TO ENERGY-TISSUE INTERACTIONS
3 credits.

Explore physical interactions between thermal, electromagnetic and acoustic energies and biological tissues with emphasis on therapeutic medical applications.
Requisites: PHYSICS 202, 208, 248, or PHYSICS/MED PHYS 265, or graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2025
Learning Outcomes: 1. Derive and solve bioheat transfer problems relevant to therapeutic hyperthermia and hypothermia
Audience: Both Grad & Undergrad

2. Explain changes at the tissue and cellular levels during thermal therapies
Audience: Both Grad & Undergrad

3. Analyze technologies that apply electromagnetic and acoustic energy to tissue
Audience: Both Grad & Undergrad

4. Discuss medical applications and regulatory guidelines/requirements involving energy-tissue interactions
Audience: Both Grad & Undergrad

5. Demonstrate an advanced ability to synthesize recent literature, formulate technical problems, and describe plausible solutions
Audience: Graduate

B M E 545 – ENGINEERING EXTRACELLULAR MATRICES
3 credits.

Overview of the structure, function and biophysical properties of extracellular matrix (ECM) proteins, followed by discussion of how control or manipulation of ECM protein expression and distribution impacts on cell and tissue function, concluding with impacts of engineering ECM for regenerative medicine.
Requisites: B M E/PHM SCI 430, graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Describe the structure and function of individual ECM components and their relevance to physiological and pathophysiological processes
Audience: Both Grad & Undergrad

2. Apply biological knowledge of the ECM to inform the manipulation, mimicking, or engineering of ECM-based systems
Audience: Both Grad & Undergrad

3. Critically evaluate ECM engineering approaches
Audience: Both Grad & Undergrad

4. Apply advanced knowledge of bioconjugate chemistry to design dynamic scaffold platforms
Audience: Graduate

B M E 550 – INTRODUCTION TO BIOLOGICAL AND MEDICAL MICROSYSTEMS
3 credits.

Introduction to the field of MEMS (Micro-Electro-Mechanical-Systems), as it applies to biology and medicine. Topics will cover methodology of traditional MEMS devices, how they can be incorporated with biological systems, and methods for micro-structuring biological materials.
Requisites: B M E 310 and (ZOOLOGY/BIOLOGY 101 and 102, ZOOLOGY/BIOLOGY/BOTANY 151, ZOOLOGY 153, or BIOCORE 383), graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Identify prominent materials and their properties commonly used in fabrication of biomedical microdevices
Audience: Both Grad & Undergrad

2. Analyze and implement microfabrication techniques for patterning, lithography, etching and deposition
Audience: Both Grad & Undergrad

3. Understand and design fabrication processes with appropriate fabrication tools for biomedical microdevices
Audience: Both Grad & Undergrad

4. Describe the principles underlying the interface between biological samples and different microdevices
Audience: Both Grad & Undergrad

5. Analyze, demonstrate, and communicate recent scientific literature in the field of biomedical microdevices
Audience: Graduate

B M E 556 – SYSTEMS BIOLOGY: MAMMALIAN SIGNALING NETWORKS
3 credits.

Introduction to the experimental and mathematical modeling techniques used in systems biology through lectures and critical analyses of relevant publications with a primary focus on gene/protein networks and mammalian systems.
Requisites: (MATH 319, 320, or 375), (B M E 510, ZOOLOGY 470, 570, PSYCH/ZOOLOGY 523, or BIOCORE 383) and Junior Standing, graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2022
Learning Outcomes: 1. Describe the structure and function of individual extracellular matrix (ECM) components and their relevance to physiological and pathophysiological processes
Audience: Both Grad & Undergrad

2. Apply biological knowledge of the ECM to inform the manipulation, mimicking, or engineering of ECM-based systems
Audience: Both Grad & Undergrad

3. Critically evaluate ECM engineering approaches
Audience: Both Grad & Undergrad

4. Apply advanced knowledge of bioconjugate chemistry to design dynamic scaffold platforms
Audience: Graduate

B M E/CBE 560 – BIOCHEMICAL ENGINEERING
3 credits.

Properties of biological molecules; enzyme kinetics, enzyme reactors, and enzyme engineering; metabolic engineering; microbial growth kinetics; bioreactor design; bioseparations.
Requisites: Junior standing and (ZOOLOGY/BIOLOGY 101 and 102, ZOOLOGY/BIOLOGY/BOTANY 151, ZOOLOGY 153, or BIOCORE 383), graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Apply principles of chemical engineering in the analysis and design of industrial biochemical processes
Audience: Both Grad & Undergrad

2. Describe the role chemistry plays in understanding how bio-molecules and bio-molecular systems work
Audience: Both Grad & Undergrad

3. Extract, communicate and critique key idea(s) from any work of the current technical literature
Audience: Both Grad & Undergrad

4. Identify opportunities for biochemical engineering to address societal needs (e.g., energy, health, materials, food, and the environment)
Audience: Both Grad & Undergrad

5. Demonstrate how chemical engineering principles can be applied to alter the molecular properties of a biological system
Audience: Graduate

B M E/I SY E 564 – OCCUPATIONAL ERGONOMICS AND BIOMECHANICS
3 credits.

Introduces engineers how to design manufacturing and industrial operations in which people play a significant role, so that human capabilities are maximized, physical stress is minimized, and workload is optimized. Examples and topics emphasize industrial applications.
Requisites: PSYCH/I SY E 349 or B M E 315, graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Evaluate jobs, equipment, tools, products, and environments, in which people play a significant role, for health and safety hazards and the risk of injuries and illnesses
Audience: Both Grad & Undergrad

2. Devise how to reduce or eliminate physical stresses and the risk of injuries and illnesses in jobs, equipment, tools, products, and environments

Audience: Both Grad & Undergrad

3. Design jobs, workspaces and products for a diverse work population, to accommodate the variability of human dimensions strength, endurance, and physical capacity to do work
Audience: Both Grad & Undergrad

4. Design jobs equipment, tools, products, and environments so that human capabilities are maximized, physical stress is minimized, and workload is optimized
Audience: Both Grad & Undergrad

5. Identify fundamental physiological principles and biomechanical theories that are germane to the evaluation, design and reduction or elimination of stresses and strain in jobs, equipment, tools, products, and environments
Audience: Graduate

B M E/MED PHYS 566 – PHYSICS OF RADIOTHERAPY
3 credits.

Ionizing radiation use in radiation therapy to cause controlled biological effects in cancer patients. Physics of the interaction of the various radiation modalities with body-equivalent materials, and physical aspects of clinical applications.
Requisites: PHYSICS/B M E/H ONCOL/MED PHYS 501
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Demonstrate knowledge of the potentials and limits, with respect to fundamental physics, of ionizing radiation production and therapy
Audience: Both Grad & Undergrad

2. Apply the concepts and/or techniques of radiation physics in cancer therapy
Audience: Both Grad & Undergrad

3. Accurately compute radiation dose and dose delivery for clinically acceptable conditions
Audience: Both Grad & Undergrad

4. Communicate applied concepts in a clear and understandable manner
Audience: Undergraduate

5. Communicate complex applied concepts in a clear and understandable manner, including concepts of medical imaging, radiation biology, radiation production, and radiation detection as they apply to radiation physics in cancer therapy
Audience: Graduate

B M E/MED PHYS 567 – THE PHYSICS OF DIAGNOSTIC RADIOLOGY
4 credits.

Physics of x-ray diagnostic procedures and equipment, radiation safety, general imaging considerations; lecture and lab.
Requisites: MATH 234 and (PHYSICS 241 or 249) or graduate/professional standing
Course Designation: Breadth - Biological Sci. Counts toward the Natural Sci req
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2018
Learning Outcomes: 1. Learn the physics and technology of medical x-ray system design and the parameters that determine image contrast, noise, spatial resolution, and patient radiation dose.
Audience: Both Grad & Undergrad

2. Gain a detailed knowledge of x-ray sources, x-ray detectors, and data acquisition strategies used in radiography, mammography, fluoroscopy, angiography and computed tomography.
Audience: Both Grad & Undergrad

3. Apply a knowledge of x-ray systems and physics to analyze and compare the performance of different medical x-ray imaging systems.
Audience: Both Grad & Undergrad

4. Through laboratory modules, receive hands on experience concerning the first three objectives. This includes learning the proper means for evaluating the performance and conducting measurements on x-ray systems which are commonly done by a clinical medical physicist.
Audience: Both Grad & Undergrad

5. Identify the defining strengths and limitations with utilizing the imaging modalities for conducting research investigations of human physiology and disease.
Audience: Graduate

B M E/MED PHYS 568 – MAGNETIC RESONANCE IMAGING (MRI)
2 credits.

Core course covering the physics associated with magnetic resonance imaging emphasizing techniques employed in medical diagnostic imaging. Major MRI topics include: physics of MR, pulse sequences, hardware, imaging techniques, artifacts, and clinical applications. At the completion of this course, students should have an understanding of the technical and scientific details of modern magnetic resonance imaging and its use in diagnosing disease. Graduate students who have not taken MATH 222 and PHYSICS 202 at UW-Madison must have the equivalent coursework in order to be successful in this course.
Requisites: Graduate/professional standing or (MATH 222 and PHYSICS 202, 208, 241, 244, 248 or 249)
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2022
Learning Outcomes: 1. Identify the mechanisms in which nuclear magnetic resonance harnessed for imaging
Audience: Both Grad & Undergrad

2. Differentiate the different MRI sequences used and the appearance of disease aspects in each of these sequences
Audience: Both Grad & Undergrad

3. Evaluate potential biological effects of imaging on patients and effects of patients on imaging
Audience: Both Grad & Undergrad

4. Contextualize the acquired knowledge to formulate research questions to solve specific clinical needs
Audience: Graduate

B M E/MED PHYS 573 – MATHEMATICAL METHODS IN MEDICAL PHYSICS
3 credits.

Mathematical fundamentals required for medical physics and biomedical applications, including signal analysis and mathematical optimization.
Requisites: (MATH 234 and 319), (MATH 234 and 320), or MATH 376 and (PHYSICS 202 or 208), graduate/professional standing, or declared in Medical Physics VISP
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Summarize the utility of signal analysis in one and several dimensions
Audience: Both Grad & Undergrad

2. Identify and apply convolutions and Fourier Transforms in one and several dimensions
Audience: Both Grad & Undergrad

3. Apply the properties of the Fourier Transform in medical physics and other biomedical settings
Audience: Both Grad & Undergrad

4. Illustrate the limitations of the Fourier transform, and recall the advantages of alternative signal analysis tools (e.g. wavelet transform)
Audience: Graduate

5. Distinguish between types of optimization problems, including convex vs non-convex, and unconstrained vs constrained
Audience: Both Grad & Undergrad

6. Recognize the relative performance of basic optimization algorithms
Audience: Both Grad & Undergrad

7. Formulate image reconstruction as an optimization problem
Audience: Both Grad & Undergrad

8. Formulate therapy planning as an optimization problem
Audience: Both Grad & Undergrad

9. Implement practical optimization algorithms using computational methods
Audience: Both Grad & Undergrad

B M E/MED PHYS 575 — DIAGNOSTIC ULTRASOUND IMAGING
2 credits.

Propagation of ultrasonic waves in biological tissues; principles of ultrasonic measuring and imaging instrumentation; design and use of currently available tools for performance evaluation of diagnostic instrumentation; biological effects of ultrasound.
Requisites: Graduate/professional standing or (MATH 234, 319, or 320 and PHYSICS 202 or 208)
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2019
Learning Outcomes: 1. Explain principles underlying ultrasound propagation and biological effects of ultrasound.
Audience: Both Grad & Undergrad

2. Apply knowledge of clinical uses and limitations/artifacts of ultrasound imaging.
Audience: Both Grad & Undergrad

3. Recall the technical details of modern medical ultrasound devices and methods to measure acoustic parameters.
Audience: Both Grad & Undergrad

4. Utilize and integrate ultrasound imaging approaches for diagnostic and therapeutic research and clinical applications.
Audience: Graduate

B M E/MED PHYS 578 — NON-IONIZING DIAGNOSTIC IMAGING
4 credits.

Covers the physics associated with magnetic resonance imaging and diagnostic ultrasound emphasizing techniques employed in medical diagnostic imaging. Major MRI topics include: physics of MR, pulse sequences, hardware, imaging techniques, artifacts, and spectroscopic localization. Ultrasound based topics covered include: propagation of ultrasonic waves in biological tissues, principles of ultrasonic measuring and imaging instrumentation, design and use of currently available tools for performance evaluation of diagnostic instrumentation, and biological effects of ultrasound. Gain an understanding of the technical and scientific details of modern non-ionizing medical magnetic resonance and ultrasound devices and their use in diagnosing disease.
Requisites: MATH 234, (MATH 319 or 320) and (PHYSICS 202, 208, 241 or 248), or graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Accurately describe, using the correct mathematics and terminology, how the signals for MRI and ultrasound are generated, the sensitivity of these techniques to tissue variations
Audience: Both Grad & Undergrad

2. Accurately describe, using the correct mathematics and terminology, spatial encoding methods for MRI and ultrasound and trade offs in imaging parameter and hardware selection
Audience: Both Grad & Undergrad

3. Identify and develop strategies to mitigate common artifacts
Audience: Both Grad & Undergrad

4. Understand how to apply the knowledge to their own research projects
Audience: Graduate

B M E/MED PHYS 580 – THE PHYSICS OF MEDICAL IMAGING WITH IONIZING RADIATION
4 credits.

Concepts and principles on the physics of medical imaging systems that form images using high energy photons are presented. Such systems are divided into two categories: (1) those based on the transmission of x-rays through the human body, including radiography, mammography, fluoroscopy, and computed tomography (CT), and (2) those based on the emission of gamma rays or annihilation radiation following radioactive decay of an internal radiolabeled molecule, including the gamma camera, single photon emission tomography (SPECT), and positron emission tomography (PET) and PET hybrid imaging systems. Emphasis is placed on understanding how physics, system design, and imaging technique determine image performance metrics such as contrast, signal-to-noise ratio, and spatial resolution. Clinical applications and radiation safety concepts are detailed for the different types of imaging systems.
Requisites: PHYSICS/B M E/H ONCOL/MED PHYS 501 and MED PHYS/B M E 573
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Identify the physical principles underlying imaging technologies used in radiology and nuclear medicine: radiography, mammography, fluoroscopy, computed tomography (CT), scintigraphy, single-photon emission tomography (SPECT), and positron emission tomography (PET).
Audience: Both Grad & Undergrad

2. Describe each imaging modality in terms of a general imaging framework in which (i) a form of energy or probe is introduced to the body, (ii) a clinically interesting signal is generated within the body, and (iii) this signal is detected and spatially localized to form an image.
Audience: Both Grad & Undergrad

3. Apply physics and engineering concepts to understand how the design and operation of an imaging system determines the contrast, noise, and spatial resolution of the images produced by the system.
Audience: Both Grad & Undergrad

4. Differentiate the characteristics of radiotracers that make them suitable for research and clinical applications in human physiology.
Audience: Both Grad & Undergrad

5. Identify the defining strengths and limitations with utilizing the imaging modalities for conducting research investigations of human physiology and disease.
Audience: Graduate

B M E 601 – SPECIAL TOPICS IN BIOMEDICAL ENGINEERING
1-3 credits.

Directed study projects as arranged with instructor.
Requisites: None
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in biomedical engineering
Audience: Undergraduate

2. Apply key theories, concepts, and methods in biomedical engineering, using appropriate tools, processes, and/or software
Audience: Undergraduate

B M E 602 – SPECIAL TOPICS IN BIOMEDICAL ENGINEERING
1-3 credits.

Special topics in biomedical engineering for graduate students or both graduate and undergraduate students together.
Requisites: None
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023
Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in biomedical engineering
Audience: Both Grad & Undergrad

2. Apply key theories, concepts, and methods in biomedical engineering, using appropriate tools, processes, and/or software
Audience: Both Grad & Undergrad

3. Apply, analyze, or evaluate advanced theories, concepts, or methods in biomedical engineering
Audience: Graduate

B M E 603 – SPECIAL TOPICS IN BIOINSTRUMENTATION AND MEDICAL DEVICES
1-3 credits.

Various special topics in bioinstrumentation and medical devices.
Requisites: None
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2025
Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in bioinstrumentation and medical devices
Audience: Both Grad & Undergrad

2. Apply key theories, concepts, and methods in bioinstrumentation and medical devices, using appropriate tools, processes, and/or software
Audience: Both Grad & Undergrad

3. Apply, analyze, or evaluate advanced theories, concepts, or methods in bioinstrumentation and medical devices
Audience: Graduate

B M E 604 – SPECIAL TOPICS IN BIOMEDICAL IMAGING AND OPTICS
1-3 credits.

Various special topics in biomedical imaging and optics.
Requisites: None
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in biomedical imaging and optics
Audience: Both Grad & Undergrad

2. Apply key theories, concepts, and methods in biomedical imaging and optics, using appropriate tools, processes, and/or software
Audience: Both Grad & Undergrad

3. Apply, analyze, or evaluate advanced theories, concepts, or methods in biomedical imaging and optics
Audience: Graduate

B M E/M E 605 – SPECIAL TOPICS IN BIOMECHANICS
1-3 credits.

Various special topics in biomechanics.
Requisites: None
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2025
Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in biomechanics
Audience: Both Grad & Undergrad

2. Apply key theories, concepts, and methods in biomechanics, using appropriate tools, processes, and/or software
Audience: Both Grad & Undergrad

3. Apply, analyze, or evaluate advanced theories, concepts, or methods in biomechanics
Audience: Graduate

B M E 606 – SPECIAL TOPICS IN BIOMATERIALS, CELLULAR AND TISSUE ENGINEERING
1-3 credits.

Various special topics in biomaterials, cellular and tissue engineering.
Requisites: None
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2025
Learning Outcomes: 1. Identify and describe key theories, concepts, and methods in biomaterials, cellular and tissue engineering
Audience: Both Grad & Undergrad

2. Apply key theories, concepts, and methods in biomaterials, cellular and tissue engineering, using appropriate tools, processes, and/or software
Audience: Both Grad & Undergrad

3. Apply, analyze, or evaluate advanced theories, concepts, or methods in biomaterials, cellular and tissue engineering
Audience: Graduate

B M E/M E 615 – TISSUE MECHANICS
3 credits.

Focus on solid mechanics of prominent musculoskeletal and cardiovascular tissues. Their normal and pathological behaviors (stiffness, strength, relaxation, creep, adaptive remodeling, etc.) in response to physiologic loading will be examined and quantified.
Requisites: M E 306 or E M A 303, or graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Mathematically and conceptually define stress and strain tensors
Audience: Both Grad & Undergrad

2. Calculate stress given a deformation and a constitutive relationship
Audience: Both Grad & Undergrad

3. Describe key features of tissue mechanics
Audience: Both Grad & Undergrad

4. Describe structure-function relationships for biological tissues
Audience: Both Grad & Undergrad

5. Summarize and present current biomechanical knowledge on a specific tissue
Audience: Graduate

B M E/MED PHYS/PHMCOL-M/PHYSICS/RADIOL 619 – MICROSCOPY OF LIFE
3 credits.

Survey of state of the art microscopic, cellular and molecular imaging techniques, beginning with subcellular microscopy and finishing with whole animal imaging.
Requisites: PHYSICS 104, 202, 208, or 248 or PHYSICS/MED PHYS 265
Course Designation: Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025

B M E 640 – MEDICAL DEVICES ECOSYSTEM: THE PATH TO PRODUCT
3 credits.

Development of medical devices for therapeutic or diagnostic purposes. Gap analysis, market analysis, reimbursement/distribution, regulatory approval, and manufacturing/supply chain development. Refinement and presentation of design ideas and corporate strategy within a team setting. Case studies of device design/manufacture including supply chain, intellectual property, pre-clinical testing, U.S. and European regulatory pathways and clinical trial design.
Requisites: B M E 402 or concurrent enrollment, graduate/professional standing, or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Develop an evolving competitive landscape analysis
Audience: Both Grad & Undergrad

2. Identify common issues in manufacturing/supply chain
Audience: Both Grad & Undergrad

3. Describe key aspects of clinical trial design
Audience: Both Grad & Undergrad

4. Discuss intellectual property both In theory and in practice
Audience: Both Grad & Undergrad

5. Articulate the differences between regulatory pathways in Europe and the United States
Audience: Graduate

6. Define key aspects of pre-clinical testing, including Quality Systems, Good Laboratory Practices, and Good Manufacturing Practices
Audience: Graduate

B M E 651 – BIOPHOTONICS LABORATORY
3 credits.

Learn and apply the fundamentals of optical imaging, microscopy and instrumentation via practical hands-on training with a specific emphasis on the life-sciences applications. Topics include constructing imaging systems using fundamental optical tools and instruments, illumination and aberrations, microscopy techniques, resolution and contrast measurement, optical spectroscopy, nanophotonics, bioimaging and biosensing.
Requisites: PHYSICS 202, 208, 248, MED PHYS/PHYSICS 265, E C E 320, 434, or graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Identify and use optical tools and instruments and construct optical imaging systems
Audience: Both Grad & Undergrad

2. Measure optical resolution and summarize parameters, such as optical aberrations, illumination and collecting optical system settings, that affect resolution in optical imaging
Audience: Both Grad & Undergrad

3. Implement Kohler illumination, identify conjugate planes and illustrate Abbe theory of image formation on a hands-on optical hardware
Audience: Both Grad & Undergrad

4. Measure contrast in different microscopy techniques and identify parameters that contribute to signal-to-background
Audience: Both Grad & Undergrad

5. Measure and analyze light spectra using filters and spectrometers to identify different light sources, and nanoparticle and light interactions
Audience: Both Grad & Undergrad

6. Follow and implement written experiment protocols, collect, and analyze data, and write coherent reports presenting experimental findings
Audience: Both Grad & Undergrad

7. Identify and evaluate an optical imaging setup that was developed in a recently published journal article applying knowledge that was learned in class
Audience: Graduate

B M E/I SY E 662 – DESIGN AND HUMAN DISABILITY AND AGING
3 credits.

Design of products for persons with physical, sensory or cognitive impairments is covered as well as the design of standard mass market products. Interdisciplinary teams explore specific disabilities, then design a standard mass market product in competition with each other.
Requisites: Junior standing or member of Engineering Guest Students
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2025
Learning Outcomes: 1. Explain the access and usability issues that users with physical, sensory, or cognitive impairments due to age or permanent or temporary disability might experience when interacting with everyday products and environmental designs
Audience: Both Grad & Undergrad

2. Apply human factors principles of universal design to describe redesign solutions for common products and environmental designs to improve accessibility for all users
Audience: Both Grad & Undergrad

3. Identify barriers to access for users based on specific disabilities
Audience: Both Grad & Undergrad

4. Articulate common misconceptions and biases related to users with disabilities and use various data sources to discuss the reality of designing for users with disabilities or impairments
Audience: Both Grad & Undergrad

5. Identify usability issues for mass-market products and environmental designs using universal design and basic access principles
Audience: Both Grad & Undergrad

6. Propose methods for improving accessibility and usability using universal design and basic access principles
Audience: Both Grad & Undergrad

7. Articulate how social, institutional, and organizational structures and insufficiently designed systems and environments disadvantage various user groups, with special focus on aging and disabled users
Audience: Graduate

B M E/CRB 670 – BIOLOGY OF HEART DISEASE AND REGENERATION
3 credits.

Presents diverse topics in contemporary heart biology to facilitate understanding of biological, mechanistic, and experimental concepts of cardiac physiology, disease, and regeneration. Learn cellular and molecular mechanisms underlying heart physiology, function, disease and regenerative ability in various model systems. Includes thinking critically about methodology, experimental design and interpretation, and how conclusions are reached in heart biology through cutting-edge literature.
Requisites: (ZOOLOGY/BIOLOGY/BOTANY 151 and BIOCHEM 501) or graduate/professional standing.
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Gain knowledge of cardiovascular physiology and biology, use of genetic model organisms, stem cell biology and regenerative medicine (didactic portion of course; attendance, and exams).
Audience: Both Grad & Undergrad

2. Understand the main themes of heart biology by reading and discussing state-of-the-art literature (journal reviews; evaluated by lecturer for each journal review session).
Audience: Both Grad & Undergrad

3. Develop ability to critically evaluate published scientific research in the cardiovascular field by discussing with peers and instructors.
Audience: Both Grad & Undergrad

4. Analyze scientific data and methodology employed in the field of heart biology.
Audience: Graduate

5. Develop ability to create an experimental design for different types of heart biology research (such as hypothesis, methodology or phenomenon driven studies).
Audience: Graduate

6. Understand the current challenges for developing therapeutic strategies for heart disease and regeneration and propose feasible approaches to resolve these challenges.
Audience: Graduate

7. Understand the concepts of techniques and methods that are currently used for cardiac biology research.
Audience: Undergraduate

8. Describe the challenges for developing therapeutic strategies for heart disease and regeneration.
Audience: Undergraduate

B M E 701 – SEMINAR IN BIOMEDICAL ENGINEERING
1 credit.

Presentation of advancements in biomedical engineering research by leaders in the field, accompanied by critical analysis of related literature.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Demonstrate understanding of technical presentations of current research in biomedical engineering
Audience: Graduate

2. Formulate and articulate a question regarding research presented in a technical seminar
Audience: Graduate

3. Analyze current scientific literature to draw connections to research presented in a technical seminar
Audience: Graduate

B M E 702 – GRADUATE COOPERATIVE EDUCATION PROGRAM
1-2 credits.

Work experience that combines classroom theory with practical knowledge of operations to provide students with a background on which to develop and enhance a professional career. The work experience is tailored for MS students from within the U.S. as well as eligible international students.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2025
Learning Outcomes: 1. Identify and respond appropriately to real-life engineering ethics cases relevant to co-op work
Audience: Graduate

2. Synthesize and apply appropriate technical education to real world technical work
Audience: Graduate

3. Communicate effectively in writing and speaking with a range of audiences in the workplace, including those without disciplinary expertise
Audience: Graduate

4. Develop professional and transferable habits like time management skills, collaborative problem-solving skills, and research skills for learning new information
Audience: Graduate

B M E 703 – RESPONSIBLE CONDUCT OF RESEARCH FOR BIOMEDICAL ENGINEERS
2 credits.

Develop an understanding of the elements involved in being a responsible member of the Biomedical Engineering research community. Topics include mentor/mentee relationships, identifying research problems, research integrity, ethics, regulations, and improving the scientific climate.
Requisites: Declared in Biomedical Engineering, Ph.D. or Biomedical Engineering: Research, M.S.
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Interpret research ethics regulations and policies
Audience: Graduate

2. Differentiate research misconduct from sloppy behavior
Audience: Graduate

3. Identify biased or hostile behaviors
Audience: Graduate

4. Develop an individualized plan for graduate training
Audience: Graduate

B M E/MED PHYS 710 – ADVANCES IN MEDICAL MAGNETIC RESONANCE
3 credits.

Addresses the theory and applications of magnetic resonance (MR) in medicine, by providing the necessary theoretical background to understand advanced MR techniques including magnetic resonance imaging (MRI).
Requisites: MED PHYS/B M E 568 or 578
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Recall and apply principles of MR signal generation, relaxation, echo generation, and spatial encoding.
Audience: Graduate

2. Compose and test concepts of advanced MR image reconstruction concepts including partial Fourier MRI, parallel MRI, non-Cartesian MRI, compressed sensing.
Audience: Graduate

3. Apply and judge image processing methods for the analysis of MR images for biomarkers such as T1 and T2 mapping and metabolite maps.
Audience: Graduate

4. Summarize and organize advanced MR applications used in the clinic and research including quantitative MRI, BOLD MRI (fMRI), MR Angiography with and without contrast agents, motion sensitive MRI, perfusion and diffusion MRI, and PET-MRI.
Audience: Graduate

5. Organize and compose concepts on sampling theory, signal-to-noise, artifacts, and pulse sequences to design protocols for MRI data acquisition, reconstruction, or processing.
Audience: Graduate

6. Demonstrate scientific communication skills for MRI research by composing oral presentations, written reports, and critiquing the work of others.
Audience: Graduate

B M E/M E 715 – ADVANCED TISSUE MECHANICS
3 credits.

Central topics in solid mechanics applied to soft tissues, including analysis of strain in the setting of large deformations, computation of stress in multiple experimental loading configurations, constitutive modeling of biomaterials using hyperelastic strain-energy functions, modeling tissue growth and remodeling, and the main theories for soft tissue failure will be covered. Application of finite elasticity theory in practical laboratory situations, and key papers and concepts in soft tissue mechanics.
Requisites: (M E/B M E 615, E M A 710, or 622 prior to Fall 2024) and graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Compute strain from multiple different types of marker and image data
Audience: Graduate

2. Compute stresses using data from uniaxial, biaxial, and inflation mechanical tests
Audience: Graduate

3. Construct and utilize constitutive models appropriate for soft tissues
Audience: Graduate

4. Formulate and analyze continuum models of biological growth
Audience: Graduate

5. Identify common failure criteria applied to soft tissues
Audience: Graduate

B M E 740 – BIOMANUFACTURING ENTREPRENEURSHIP
3 credits.

Industry-relevant concepts of biotechnology innovation and translation, directly connecting lessons and classwork to real-world experience and career opportunities and promoting meaningful and sustained engagement between students and industry representatives. Diverse range of translational biotechnology principles, such as product development in biotechnology, regulating biotechnology products, and quality and compliance in biomanufactured products.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Recall, differentiate, and interpret key terms of art and jargon commonly associated with translation, commercial development, and regulation of novel biotechnologies and human therapies
Audience: Graduate

2. Describe common tools and strategies used by biotechnology industry to assess project progress, risk, and overall value
Audience: Graduate

3. Identify and evaluate business strategy and technology translation approach of a real biotech start-up company applying knowledge that was learned in class
Audience: Graduate

4. Produce a product-focused value proposition based on the student's research topic, or of a technology of interest to the student by integrating aspects of a business model canvas and constructing a strategic technology development plan
Audience: Graduate

B M E/CHEM/MED PHYS 750 – BIOLOGICAL OPTICAL MICROSCOPY
3 credits.

Covers several aspects of state-of-the-art biological and biophysical imaging with an emphasis on instrumentation, beginning with an overview of geometrical optics and optical and fluorescence microscopy. The bulk of the course will focus on advanced imaging techniques including nonlinear optical processes (multi-photon excitation, second harmonic generation, and stimulated Raman processes) and emerging super-resolution methods. Special emphasis will be given to current imaging literature and experimental design. Knowledge of physics-based optics [such as PHYSICS 202] strongly recommended.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2021
Learning Outcomes: 1. Provide a clear, concise oral presentation critiquing a paper in the literature
Audience: Graduate

2. Write a hypothesis driven research proposal and present an oral defense
Audience: Graduate

3. Write a critical written assessment of literature papers
Audience: Graduate

4. Use course concepts to better design experiments and extract quantitative information
Audience: Graduate

5. Articulate a fundamental understanding of the function of a microscope

Audience: Graduate

B M E 751 – BIOMEDICAL OPTICS AND BIOPHOTONICS
3 credits.

The study and use of light in the life sciences. Interactions of light with cells and tissue can be used for imaging, measurement, diagnosis, and therapy. Applications include optical imaging, endoscopy, microscopy, resolution enhancement, adaptive optics, Optical Coherence Tomography (OCT), quantitative phase microscopy, spectroscopy (fluorescence, elastic scattering), diffuse optical tomography, and computational modeling of light transport in tissue. Fundamental skills, concepts, and theory used for these applications include geometric optics, lens design, Fourier transforms, polarization, interference, coherence, and scattering theory. Particular emphasis will be placed on current literature and cutting edge instruments and methods.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2021
Learning Outcomes: 1. identify common optical components and describe their fundamental principles
Audience: Graduate

2. select an appropriate technique or technology best suited to solve a given research or medical problem and explain the rationale
Audience: Graduate

3. solve optical design problems including 1st order optical design of a scanning light microscope
Audience: Graduate

4. orally present and critique a recent journal article with a succinct description of the optical methods or concepts employed and evaluate the pros and cons
Audience: Graduate

B M E 770 – NANOTECHNOLOGY IN NEUROSCIENCE
2 credits.

Principles of micro- and nano-technology applied to neuroscience, including technological approaches applied to both in vitro and in vivo neurobiological experimentation and neurology. Fundamentals of recording and processing neural signals using nanoscale synthesis processes and technologies including nanostructured electrodes and their electrical, mechanical, and biochemical properties, active and passive 2D and 3D multielectrode arrays (MEAs), nanoscale transistors for subcellular recordings, nanoparticles, and nano-synthesized agents for recording and stimulating neural activity. Relevant theory of cell electrode coupling, electrophysiology, and neurochemical signaling. Knowledge of microfabrication technologies and biology [such as in B M E 550] recommended.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026
Learning Outcomes: 1. Evaluate nerve cell signaling and apply signal processing methods for analyzing neural signals
Audience: Graduate

2. Create nanofabrication processes for designing nano-scale patterning neural recording devices
Audience: Graduate

3. Analyze neuron-device interface and compute coupling using equivalent electrical circuit models
Audience: Graduate

4. Evaluate chemical synthesis techniques for biocompatible device coating, cell patterning, and nanoparticle-based sensing
Audience: Graduate

B M E/E C E/MED PHYS 778 — MACHINE LEARNING IN ULTRASOUND IMAGING
3 credits.

Concepts and machine learning techniques for ultrasound beamforming for image formation and reconstruction to image analysis and interpretation will be presented. Key machine learning and deep learning concepts applied to beamforming, compressed sampling, speckle reduction, segmentation, photoacoustics, and elasticity imaging will be evaluated utilizing current peer-reviewed publications.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Critically read and evaluate peer-reviewed journal papers describing machine learning applications in ultrasound imaging.
Audience: Graduate

2. Apply, implement and expand upon ideas from these publications to applications in ultrasound imaging.
Audience: Graduate

3. Present the results of their critical evaluation and implementation to the class.
Audience: Graduate

4. Write a research paper based on their findings suitable for publication.
Audience: Graduate

B M E 780 — METHODS IN QUANTITATIVE BIOLOGY
1 credit.

Focuses on understanding the key methods and principles of quantitative biology through a close reading of the primary literature. Topics covered will include deterministic and stochastic methods for modeling cellular systems, techniques in systems and synthetic biology, image processing tools and image analysis for biology, data-driven network models, genomic approaches, single-molecule approaches, and key computational biology tools. This course is intended for graduate students from a variety of backgrounds who are interested in pursuing quantitative biology during their graduate studies.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2025
Learning Outcomes: 1. Identify and describe the benefits and limitations of key methods used in the field of quantitative biology
Audience: Graduate

2. Critically evaluate experimental and theoretical papers in quantitative biology
Audience: Graduate

B M E/CBE 783 — DESIGN OF BIOLOGICAL MOLECULES
3 credits.

Introduction to the methodologies for engineering the structure and function of biological molecules, especially proteins. Develop an understanding for the integration of computation and experiment to address biological molecular engineering problems. Knowledge of biochemistry and cell biology [such as BIOCHEM 501 or ZOOLOGY 570] required.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2026

B M E 790 — MASTER'S RESEARCH AND THESIS
1-9 credits.

Under faculty supervision.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Integrate knowledge from a subset of the biological and physical sciences to address a research question
Audience: Graduate

2. Conduct a research study using experimental, computational, and/or theoretical approaches
Audience: Graduate

3. Communicate research results in a written thesis and defense
Audience: Graduate

B M E 799 — ADVANCED INDEPENDENT STUDY
1-5 credits.

Under faculty supervision.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Conduct and report on an independent biomedical engineering project
Audience: Graduate

2. Appropriately utilize online and library resources
Audience: Graduate

3. Connect their research clearly to other research in their field of study
Audience: Graduate

B M E 890 — PRE-DISSERTATION RESEARCH
1-9 credits.

Under faculty supervision.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Integrate knowledge from a subset of the biological and physical sciences to address a research question
Audience: Graduate

2. Recognize and apply appropriate ethical and regulatory principles
Audience: Graduate

3. Conduct preliminary studies using experimental, computational, and/or theoretical approaches
Audience: Graduate

4. Generate and defend a research proposal
Audience: Graduate

B M E/B M I/BIOCHEM/CBE/COMP SCI/GENETICS 915 — COMPUTATION AND INFORMATICS IN BIOLOGY AND MEDICINE
1 credit.

Participants and outside speakers will discuss current research in computation and informatics in biology and medicine. This seminar is required of all CIBM program trainees.
Requisites: Consent of instructor
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Discuss how methods from computer science, statistics, information science and engineering are applied to problems in biology, medicine and population health
Audience: Graduate

2. Recognize and be able to define applications in translational bioinformatics, clinical informatics and public health informatics
Audience: Graduate

B M E 990 — RESEARCH AND THESIS
1-9 credits.

Under faculty supervision.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2026
Learning Outcomes: 1. Integrate knowledge from a subset of the biological and physical sciences to address a research question
Audience: Graduate

2. Recognize and apply appropriate ethical and regulatory principles
Audience: Graduate

3. Conduct a research study using experimental, computational, and/or theoretical approaches
Audience: Graduate

4. Communicate research results in a written thesis and defense
Audience: Graduate

B M E 999 — ADVANCED INDEPENDENT STUDY
1-9 credits.

Under faculty supervision.
Requisites: Declared in Biomedical Engineering PhD or professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2019
Learning Outcomes: 1. Conduct and report on an independent biomedical engineering project
Audience: Graduate

2. Appropriately utilize online and library resources
Audience: Graduate

3. Connect their research clearly to other research in their field of study
Audience: Graduate