Bioengineering (BIOE)

Courses

BIOE 1990. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 2350. Biomechanics. (4 Hours)
Designed to acquaint students with concepts of stress, strain, and constitutive laws as applied to problems in biomechanics. Introduces rigid body and deformable body mechanics. Focuses on basic foundations of solid mechanics using vectors and tensors. Illustrative examples from tissue and cell biomechanics are given where appropriate.

Prerequisite(s): (MATH 1252 with a minimum grade of D- or MATH 1342 with a minimum grade of D-); (PHYS 1151 with a minimum grade of D- or PHYS 1161 with a minimum grade of D- or PHYS 1171 with a minimum grade of D-)

BIOE 2355. Quantitative Physiology for Bioengineers. (4 Hours)
Introduces engineering and science students to core knowledge and understanding of physiological systems and processes. Focuses on quantitative analysis of human physiological systems. Topics include the physical and chemical foundations of physiology; coupled forces and flows; electrical, mechanical, and chemical potentials and their conjugated fluxes; and the physiology of excitable tissue. Examines cell structure, function, and homeostasis with a particular focus on membrane transport, osmotic pressure, cell signaling, and cellular energetics.

Prerequisite(s): MATH 2341 (may be taken concurrently) with a minimum grade of D- ; (CHEM 1151 with a minimum grade of D- or CHEM 1161 with a minimum grade of D- or CHEM 1211 with a minimum grade of D- or CHEM 1217 with a minimum grade of D-); (PHYS 1155 (may be taken concurrently) with a minimum grade of D- or PHYS 1165 (may be taken concurrently) with a minimum grade of D- or PHYS 1175 (may be taken concurrently) with a minimum grade of D-)

BIOE 2365. Bioengineering Measurement, Experimentation, and Statistics. (4 Hours)
Introduces the fundamentals of biomedical data acquisition and statistical analysis. Engineering statistics topics include descriptive statistics, probability distributions, hypothesis testing, analysis of variance, and experiment design. Applies these statistical topics by analyzing data obtained from laboratory exercises in BIOE 2366. Laboratory exercise topics include cell culture, mechanical testing, modeling medical imaging data, 3D printing, and bioprinting. Emphasizes using MATLAB software to analyze data on the computer.

Prerequisite(s): (BIOL 1107 (may be taken concurrently) with a minimum grade of D- or BIOL 1111 (may be taken concurrently) with a minimum grade of D- or BIOL 1115 (may be taken concurrently) with a minimum grade of D-); (MATH 1252 (may be taken concurrently) with a minimum grade of D- or MATH 1342 (may be taken concurrently) with a minimum grade of D-); (ENGW 1111 with a minimum grade of C or ENGW 1102 with a minimum grade of C)
Corequisite(s): BIOE 2366
Attribute(s): NUpath Analyzing/Using Data, NUpath Writing Intensive

BIOE 2366. Lab for BIOE 2365. (1 Hour)
Offers associated laboratory exercises for BIOE 2365. Requires lab reports from all students.

Corequisite(s): BIOE 2365

BIOE 2949. Introductory Directed Research in Bioengineering. (4 Hours)
Offers an opportunity to pursue project and other independent inquiry opportunities under faculty supervision for first- and second-year students. The course is initiated with a student-developed proposal, including expected learning outcomes and research products, which is approved by a faculty member in the department. Permission of instructor required.

BIOE 2990. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 2992. Research. (0 Hours)
Offers an opportunity to document student contributions to research projects or creative endeavors. May be repeated up to nine times.

BIOE 3210. Bioelectricity. (4 Hours)
Discusses principles of electrical circuit theory and analysis methods for understanding and designing biomedical devices and biological sensors. Covers basic circuit components, network analysis methods, RC and RL circuits, AC circuit analysis, equivalent circuits, biopotential amplifiers, and biopotential electrodes. Introduces biosensing, biosignal processing, and operating principles of electrically active cells and tissues.

Prerequisite(s): (MATH 2321 with a minimum grade of D- ; MATH 2341 with a minimum grade of D-); (PHYS 1155 with a minimum grade of D- or PHYS 1165 with a minimum grade of D- or PHYS 1175 with a minimum grade of D-)

BIOE 3310. Transport and Fluids for Bioengineers. (4 Hours)
Covers the fundamental principles of processes and systems in which mass, energy, and momentum are transported in typical biological problems. Emphasizes momentum transport for incompressible and compressible fluids (fluid flow) and energy transport. The methods taught are relevant to the analysis of physiological systems, processing, and separation of biological materials.

Prerequisite(s): BIOE 2350 with a minimum grade of D- ; BIOE 2355 with a minimum grade of D- ; (MATH 2321 with a minimum grade of D- ; MATH 2341 with a minimum grade of D-)

BIOE 3380. Biomolecular Dynamics and Control. (4 Hours)
Focuses on the principles of thermodynamics and kinetics applied to the analysis and design of biomolecular systems. Covers foundational topics—such as mass and energy balances, chemical equilibria, and enzyme kinetics—in a biological context. Introduces the role of feedback and feed-forward control in biomolecular networks, emphasizing basic analytical and computational methods, including the use of MATLAB, for analyzing how these regulatory structures affect the dynamics of small-scale, prototypical networks.

Prerequisite(s): (MATH 2321 with a minimum grade of D- ; MATH 2341 with a minimum grade of D-); BIOE 2355 with a minimum grade of D-

BIOE 3410. Experimental Laboratory Methods. (4 Hours)
Offers advanced bioengineering laboratory exercises with emphasis on techniques central to molecular, cellular, and tissue engineering. Laboratory exercise topics include PCR and qPCR, protein chemistry, bioconjugation, enzyme kinetics and enzyme-substrate interactions, polymers, surface modification, 3D bioprinting, fluorescence microscopy, and image analysis. Students build on previous courses by applying experimental design concepts, including sample size selection for statistical power, repeats vs. replicates, experimental treatments and groupings for ANOVA and mixed model analysis, and designing a robust standard curve, to research questions. Students apply MATLAB, microscopy imaging software, and molecular visualization and docking software to analyze experimental data. Requires in-class participation and written lab assignments and reports from all students.

Prerequisite(s): BIOE 2365 with a minimum grade of D- ; BIOE 2366 with a minimum grade of D-

BIOE 3990. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 4790. Capstone Design 1. (4 Hours)
Offers the first in a two-course sequence of capstone design. Introduces principles of engineering design and applies them to the design of bioengineered devices. Topics consist of ethics, cost engineering, research methods, intellectual property, technical report writing, and FDA design control—including inputs, outputs, verification, validation, and design history files. Students are formed into teams and paired with a faculty advisor and supporter. Project support can be departmental, industrial, or external. Students defend a preliminary design project proposal in written and oral form before a faculty jury.

Attribute(s): NUpath Capstone Experience, NUpath Creative Express/Innov, NUpath Writing Intensive

BIOE 4792. Capstone Design 2. (4 Hours)
Continues BIOE 4790. Offers students an opportunity to apply design principles to create a device or process to solve a relevant bioengineering problem. Teams develop, construct, and evaluate prototypes under real-world fiscal, regulatory, and safety conditions. Progress is monitored through a series of oral presentations in design gate review meetings. The design process is documented in a design history file that is reviewed throughout the course. Requires students to complete a working prototype or simulation, as appropriate, and a final written report.

Prerequisite(s): BIOE 4790 with a minimum grade of D-
Attribute(s): NUpath Capstone Experience, NUpath Creative Express/Innov, NUpath Writing Intensive

BIOE 4970. Junior/Senior Honors Project 1. (4 Hours)
Focuses on in-depth project in which a student conducts research or produces a product related to the student's major field. Combined with Junior/Senior Project 2 or college-defined equivalent for 8-credit honors project. May be repeated without limit.

BIOE 4971. Junior/Senior Honors Project 2. (4 Hours)
Focuses on second semester of in-depth project in which a student conducts research or produces a product related to the student's major field. May be repeated without limit.

Prerequisite(s): BIOE 4970 with a minimum grade of D-

BIOE 4990. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 4991. Research. (4 Hours)
Offers an opportunity to conduct research under faculty supervision. May be repeated without limit.

Attribute(s): NUpath Integration Experience

BIOE 4992. Directed Study. (1-4 Hours)
Offers theoretical or experimental work under the direction of members of the department under a chosen topic. Course content depends on instructor. May be repeated without limit.

BIOE 5060. Special Topics in Bioengineering. (4 Hours)
Focuses on topics of timely interest to students of science and engineering. Topic varies from semester to semester. When appropriate, the course takes advantage of unique opportunities afforded by visiting faculty and guests. May be repeated once.

BIOE 5115. Dynamical Systems in Biological Engineering. (4 Hours)
Introduces the theoretical analysis and modeling of dynamical systems in biology, ranging from molecular to population applications. Topics include difference and differential equation models, with basic theory including nondimensionalization, steady states, linearization, stability, eigenvalues, global behavior, singular perturbations, multistability, hysteresis, cooperativity, periodic solutions, excitable systems, bifurcations; and an introduction to spatial (PDE) models. Develops all concepts in the context of concrete biological applications, such as gene regulation; chemical reaction networks and stoichiometry; drug models and PK/PD; receptor/ligand interactions; synthetic constructs; action potential generation; enzymatic reactions; population interactions; epidemiology; epigenetic phenomena, including differentiation and transport; chemotaxis; and diffusion.

Prerequisite(s): MATH 2341 with a minimum grade of D- or graduate program admission

BIOE 5235. Biomedical Imaging. (4 Hours)
Presents the foundations of modern medical imaging, including imaging principles, imaging mathematics, imaging physics, and image-generation techniques. Includes X-ray, ultrasound, computed tomography, and magnetic resonance imaging.

Prerequisite(s): BIOE 3210 with a minimum grade of D- or graduate program admission

BIOE 5250. Regulatory and Quality Aspects of Medical Device Design. (4 Hours)
Covers engineering design challenges intrinsic to the development of biomedical devices, including clinical evaluation, manufacture, and testing of medical devices and the constraints that FDA regulations place on these processes. Topics include quality systems, design control, cybersecurity concerns, the role of standards in global device regulation, and the design process. Students are asked to form teams and to carry out a semester-long conceptual design project to develop a design overview, design plan, design input specifications, and verification test procedures for a novel medical device.

BIOE 5410. Molecular Bioengineering. (4 Hours)
Introduces the fundamentals of molecular structure and function that underpin engineering of biological macromolecules. Builds on this base with the application of design concepts for molecules and methods of structural and functional analyses and strategies for design and redesign of therapeutic molecules. Projects seek to provide students with experience in conceptual design to create strategies to address significant health concerns.

Prerequisite(s): ((BIOL 1111 with a minimum grade of D- or BIOL 1115 with a minimum grade of D-); MATH 1342 with a minimum grade of D-) or graduate program admission

BIOE 5411. Applied Molecular Bioengineering. (4 Hours)
Examines the fundamentals of molecular structure and function within cellular systems, and studies how to build tools based on those fundamental principles for manipulating or analyzing biological systems. Covers a range of topics including chemical structure of biological macromolecules; central dogma; tools to synthesize, perturb, and analyze biological macromolecules; as well as more applied topics including gene therapies and vaccine development. Emphasizes design principles of molecular bioengineering, developing familiarity with publicly available molecular biology software and databases, as well as science communication.

BIOE 5420. Cellular Engineering. (4 Hours)
Analyzes the techniques that form the foundation of molecular cell engineering, including recombinant DNA, cloning and genomics, prokaryotic and eukaryotic gene regulation and single-cell gene expression, structure, dynamics of gene regulatory networks, metabolism and cellular energetics, cell structure, cytoskeleton and cellular motors, synthetic gene circuits, and metabolic engineering.

Prerequisite(s): BIOE 2355 (may be taken concurrently) with a minimum grade of D- or graduate program admission

BIOE 5430. Principles and Applications of Tissue Engineering. (4 Hours)
Applies the principles of biology and biomedical engineering to the creation of artificial organs for transplantation, basic research, or drug development. Requires integration of knowledge of organic chemistry, cell biology, genetics, mechanics, biomaterials, nanotechnology, and transport processes to create functional organs. Reviews basic cell culture techniques, structure function relationships, cellular communication, natural and artificial biomaterials, and the basic equations governing cell survival and tissue organization.

Prerequisite(s): BIOE 2355 (may be taken concurrently) with a minimum grade of D- or graduate program admission

BIOE 5440. The Cell as a Machine. (4 Hours)
Introduces the key roles that physical forces, the extracellular matrix, and cytoskeletal structure play in the development of human diseases. The cell is viewed as an engineering system that is capable of sensing physical cues from its environment, integrating such information from different mechano-sensors, and responding to changes in its external environment in a coherent manner. Uses mathematical and computational models to explain how cells sense and respond to physical cues.

Prerequisite(s): ((BIOE 3380 with a minimum grade of D- ; BIOE 2350 with a minimum grade of D-) or ME 2355 with a minimum grade of D-) or graduate program admission

BIOE 5450. Stem Cell Engineering. (4 Hours)
Covers engineering principles and approaches in stem cell research and their application in tissue engineering and regenerative medicine. Emphasizes recent technology and engineering tools used to understand and manipulate stem cells. Topics covered include embryonic and adult stem cell biology fundamentals; quantitative modeling of stem cell signaling; genetic/biochemical/biophysical/biomechanical/biomaterials tools to control stem cell fate and differentiation; epigenetic editing and cellular reprogramming; engineering biomimetic and bioreactor environments to develop stem-cell-based therapies; and various applications in tissue development, diseases, and regeneration.

Prerequisite(s): (BIOE 5420 with a minimum grade of C- or BIOE 5420 with a minimum grade of D-); (BIOE 5430 with a minimum grade of C- or BIOE 5430 with a minimum grade of D-)

BIOE 5510. Bioengineering Products/Technology Commercialization. (4 Hours)
Focuses on the translation and commercialization of bioengineering products and technology. Offers students an opportunity to gain essential entrepreneurship skills through studying and exercising the key elements and processes in establishing and launching a biotechnology startup. Examines how to assess bioengineering product and technology opportunities, evaluate the technology's market potential, navigate the landscape of intellectual property protection and FDA regulation for bioengineering products, form a biotechnology startup company, write a business plan, and pitch startups to prospective investors. Covers fundamentals of engineering economics.

BIOE 5630. Physiological Fluid Mechanics. (4 Hours)
Analyzes biofluids and their mechanics, including cardiovascular fluid mechanics. Examples are taken from biotechnology processes and physiologic applications, including the cardiovascular, respiratory, ocular, renal, musculoskeletal, and gastrointestinal systems. Topics include dimensional analysis, particle kinematics in Eulerian and Lagrangian reference frames, constitutive equations and Newtonian/non-Newtonian biofluid models, flow and wave propagation in flexible tubes, and oscillatory and pulsatile flows.

Prerequisite(s): (BIOE 3310 with a minimum grade of D- or ME 3475 with a minimum grade of D- or ME 3480 with a minimum grade of D-) or graduate program admission

BIOE 5640. Computational Biomechanics. (4 Hours)
Identifies and reviews the fundamental conservation principles that govern structural mechanics and fluid dynamics in biological systems. Discusses the following numerical analysis techniques: parameter estimation, finite difference, numerical integration, and finite element methods. By combining conservation laws with numerical analyses techniques, develops approaches to describe the physiological function of various biological systems, allowing for a system of equations to be used to describe a biological problem and solve this system numerically to predict its behavior.

BIOE 5648. Biomedical Optics. (4 Hours)
Covers biomedical optics and discusses the theory and practice of biological and medical applications of lasers. Topics covered include fundamentals of light propagation in biological tissues; light-matter interactions such as elastic and inelastic scattering; fluorescence and phosphorescence; diagnostic imaging techniques such as confocal fluorescence microscopy, diffuse optical tomography, and optical coherence tomography; and therapeutic interventional techniques, including photodynamic therapy, laser thermal therapies, and fluorescence-guided surgeries. EECE 5648 and BIOE 5648 are cross-listed.

Prerequisite(s): BIOE 3210 with a minimum grade of D- or EECE 2150 with a minimum grade of D- or graduate program admission

BIOE 5660. Integrative Mechanobiology. (4 Hours)
Introduces integrative approaches to mechanobiology, from molecular and cell behavior to multicellular, tissue, and organ environments. Covers mechanical basis of life, cytoskeletal forces and structure, rheological properties of cells, mechanobiology technologies and models, mechanics of cancer, embryogenic development and stem cells, and aging. Discusses critical issues facing mechanobiology for solving medical and health problems.

Prerequisite(s): BIOE 2350 with a minimum grade of D- or graduate program admission

BIOE 5710. Experimental Systems and Synthetic Bioengineering. (4 Hours)
Introduces experimental aspects of systems and synthetic bioengineering. Offers students an opportunity to learn how to plan and execute quantitative experiments, how to apply engineering principles to design laboratory research and to interpret data, and how to design and implement synthetic genetic or enzymatic circuits. Through team projects, explores techniques in nucleic acid, protein, and genetic engineering; quantitative measurements at the single-cell level and beyond; design and applications of synthetic circuits; and discusses ethical considerations.

Prerequisite(s): BIOE 2355 with a minimum grade of D- or graduate program admission

BIOE 5720. Physical Bioengineering. (4 Hours)
Covers biopolymer conformations, cell membrane mechanics, chemical reaction kinetics and applications to polymerization and molecular motors, electric fields, and action potential propagation. Recent years have seen a tremendous growth in the use of ideas and methods from physical science and engineering to obtain a better understanding of biological phenomena and for applications of that understanding to societal needs, ranging from health to agriculture. Underlying these efforts are principles from statistical physics that establish the framework for this increasingly popular part of bioengineering.

Prerequisite(s): BIOE 2365 with a minimum grade of D- or BIOE 3380 with a minimum grade of D- or graduate program admission

BIOE 5750. Modeling and Inference in Bioengineering. (4 Hours)
Develops a set of statistical tools to address poorly posed inverse problems. Interpreting complex and partial information is a routine task in research as well as in our daily lives. Such tasks include estimating quantitative properties of a biological system from indirect noisy measurements, responding to fluctuating environmental signals, or breaking encrypted messages. Common to these diverse questions is a need to construct a predictive model from partial data. Draws on examples from primary literature in biology to study text recognition, trait mapping, sequence alignment, decoding cryptographs, processing of chemoattractive signals to find food, and survival strategies of bacteria in unpredictable environments.

Prerequisite(s): ((MATH 2321 with a minimum grade of D- ; MATH 2341 with a minimum grade of D-); (BIOE 2365 with a minimum grade of D- or (CHME 3315 with a minimum grade of D- ; CHME 4315 with a minimum grade of D-))) or graduate program admission

BIOE 5800. Systems, Signals, and Controls for Bioengineers. (4 Hours)
Explores the concept of systems and transfer functions to allow engineers to break down a complex system into simpler systems and to combine simpler modules to form complex functions. Presents a set of analytical tools and focuses on applying frequency-domain analyses (e.g., Fourier, Laplace, and Z transforms) to simplify continuous and discrete-time systems and gain insights regarding their stability and frequency responses. Offers students an opportunity to understand, characterize, and combine analog and digital signals produced by electronic and biological circuits, as well as design controllers to achieve desired biosystem behavior. Using this knowledge, students design filters and controllers, both in the analog and digital forms, and measure and manipulate complex real-world bioengineering systems (including image processing for 2D signals).

Prerequisite(s): BIOE 3210 with a minimum grade of D- or graduate program admission

BIOE 5810. Design of Biomedical Instrumentation. (4 Hours)
Investigates the principles of biology and engineering underlying the design and use of biomedical instrumentation. Topics include design of a broad range of instrumentation and monitoring devices, sensors, and integrated systems. Graduate students interested in taking this course should have completed an equivalent introductory circuits course.

Prerequisite(s): (BIOE 2365 with a minimum grade of D- ; BIOE 3210 with a minimum grade of D-) or graduate program admission

BIOE 5820. Biomaterials. (4 Hours)
Offers a broad overview of the field of biomaterials (materials used in medical devices that interact with living tissues). Introductory lectures cover biomaterials and their translation from the laboratory to the medical marketplace. Discusses important biomaterials terminology and concepts. Emphasizes material structure-property-function-testing relationships and discusses specific materials used in medical devices and drug delivery. Concludes with introductions to topics in the field, such as biomaterials-tissue interactions, tissue engineering, and regulatory requirements. Considers principles of device design as related to the selection and application of biomaterials.

Prerequisite(s): (CHEM 1151 with a minimum grade of D- or CHEM 1161 with a minimum grade of D- or CHEM 1211 with a minimum grade of D- or CHEM 1217 with a minimum grade of D-) or graduate program admission

BIOE 5850. Design of Implants. (4 Hours)
Uses an interdisciplinary approach to evaluate how a team designs medical implants to meet unmet clinical needs. Covers biomaterials, interfacial phenomena/surface science, phenomena/surface science, the lymphatic system, immune response, aging, mechanical factors, sterilization methods, and human factors. Presents exogenous factors, including intellectual property, regulatory requirements, affordability, product liability, and bioethics. The class is divided into teams that design proprietary medical devices using a unit processes/case study approach presented by experts with firsthand experience in meeting unmet market needs.

Prerequisite(s): BIOE 5820 (may be taken concurrently) with a minimum grade of D- or BIOE 5820 (may be taken concurrently) with a minimum grade of C- (Graduate)

BIOE 5860. Engineering Approaches to Precision Medicine I. (4 Hours)
Covers the field of biomedical data science. Teams of students undertake projects solicited from biomedical PIs in broad areas of biomedical research, using datasets and developing a project work plan. Studies how to estimate a patient's state of health using their health data and to use modeling and machine learning methods to project that health state to make personalized predictions. Includes lectures on physiology, medicine, and engineering principles (probability, machine learning) relevant to each project; faculty mentors assist student projects with challenges. Requires project updates to the class at regular intervals so that teams gain experience with presenting.

Prerequisite(s): MATH 2341 with a minimum grade of D- or MATH 2331 with a minimum grade of D- or graduate program admission

BIOE 5870. Engineering Approaches to Precision Medicine II. (4 Hours)
Applies core knowledge of biomedical data science methods developed in BIOE 5860 to students' research projects under the mentorship of biomedical and engineering PIs. Research projects originate from clinical research and are designed to train students in understanding how to mathematically and computationally define and estimate a patient's state of health and how to use modeling and machine learning methods to make personalized predictions. Successfully making predictions in advance allows physicians to intervene early to help the patient.

Prerequisite(s): BIOE 5860 with a minimum grade of C-

BIOE 5880. Computational Methods in Systems Bioengineering. (4 Hours)
Introduces students to the use of computational methods in studies of systems biology, computational bioengineering, and data science and their extended utilities in a wide variety of applications in science and engineering. Covers basic elements of numerical methods and algorithms for solving different types of differential equations, running simulations, and performing optimization and data analysis. Emphasizes the concept and principle of each algorithm and its usage in R programming in the context of real-world applications in systems biology, bioinformatics, computational biology, and data science.

Prerequisite(s): BIOE 3380 with a minimum grade of D- or graduate program admission

BIOE 6000. Principles of Bioengineering. (1 Hour)
Covers the fundamentals of bioengineering research topics and methodology for master's-level bioengineering students. Internal and external speakers discuss general topics in bioengineering, including the medical device qualification and regulatory environment, tissue engineering, cell engineering, mechanobiology, drug delivery, bioimaging, neuromotor control, and effective design of experiments. Each student is expected to read, critically evaluate, and present research in a peer-reviewed bioengineering journal article.

BIOE 6100. Medical Physiology. (4 Hours)
Designed to provide bioengineering students with a working knowledge of the integrated behavior of organs and systems in the human body. As such, the student is provided with a comprehensive and intense immersion in each physiological subsystem with the expectation that he or she display knowledge of each at the level equivalent to that of a second-year medical student following his or her exposure to physiology. The specific subsystems covered are muscle physiology, cardiovascular physiology with ECG interpretation, pulmonary physiology with gas exchange mechanics and ventilation/perfusion, renal physiology and water balance, regulation of pH, gastrointestinal physiology, temperature regulation and energy balance, endocrine systems, and reproductive systems. The course does not cover neurophysiology.

BIOE 6200. Mathematical Methods in Bioengineering. (4 Hours)
Offers an overview of quantitative techniques that students will encounter in their research, providing a language and a foundation for more specialized study. Introduces basic concepts from linear algebra, ordinary and partial differential equations, transforms, function approximation, probability, statistics, and numerical computation, illustrated by applications in biology and medicine.

BIOE 6962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 7000. Principles of Bioengineering. (4 Hours)
Designed to introduce new graduate bioengineering students to the fundamentals of bioengineering research topics and methodology. Includes outside speakers to discuss general topics in bioengineering. Examples of course topics include the medical device qualification and regulatory environment, tissue engineering, cell engineering, mechanobiology, drug delivery, bioimaging, neuromotor control, effective design of experiments, writing research proposals for the National Institutes of Health (NIH) and how to evaluate and write a peer-reviewed journal article, etc. Expects students to read, critically evaluate, and present the research in a bioengineering journal article. Students are then expected to extend their article into a hypothesis-driven proposal in NIH format with an oral defense of the proposal.

BIOE 7374. Special Topics in Bioengineering. (4 Hours)
Offers topics of current interest in bioengineering. May be repeated up to nine times.

BIOE 7390. Seminar. (0 Hours)
Presents topics of an advanced nature by faculty, outside speakers, and students in the graduate program. May be repeated without limit.

BIOE 7391. Student Seminar. (0 Hours)
Offers students an opportunity to practice clear and concise oral communication of research to an audience of people with a variety of skills and differing expertise. This is an essential skill for anyone seeking a career in scientific research and beyond. It differs from communicating research to a group meeting or a conference presentation, which is comprised of audiences of fellow specialists who are already familiar with the field and its specialized terminology. Students instead present to a diverse, interdisciplinary group of peers (i.e., the Department of Bioengineering and other members of the Northeastern community). Maybe be repeated once.

BIOE 7945. Master's Project. (4 Hours)
Offers analytical and/or experimental work leading to a written report and a final short presentation by the end of the semester.

BIOE 7962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

BIOE 7976. Directed Study. (1-4 Hours)
Offers independent work under the direction of members of the department on a chosen topic. Course content depends on instructor. May be repeated twice for up to 12 semester hours.

BIOE 7986. Research. (0 Hours)
Offers students an opportunity to conduct full-time research under faculty supervision.

BIOE 7990. Thesis. (4 Hours)
Offers analytical, research, and/or experimental work conducted under the auspices of the department.

Prerequisite(s): BIOE 7945 with a minimum grade of C-

BIOE 7996. Thesis Continuation - Half-Time. (0 Hours)
Continues thesis work conducted under the supervision of a departmental faculty.

BIOE 8960. Exam Preparation—Doctoral. (0 Hours)
Offers students an opportunity to prepare for the PhD qualifying exam under faculty supervision. Intended for students who have completed all required PhD course work and have not yet achieved PhD candidacy; students who have not completed all required PhD course work are not allowed to register for this course. May be repeated once.

BIOE 8986. Research. (0 Hours)
Offers students an opportunity to conduct full-time research under faculty supervision. May be repeated without limit.

BIOE 9000. PhD Candidacy Achieved. (0 Hours)
Indicates successful completion of program requirements for PhD candidacy.

BIOE 9986. Research. (0 Hours)
Offers students an opportunity to conduct full-time research under faculty supervision. May be repeated up to nine times.

BIOE 9990. Dissertation Term 1. (0 Hours)
Offers theoretical and/or experimental work conducted under the auspices of the department.

Prerequisite(s): BIOE 9000 with a minimum grade of S

BIOE 9991. Dissertation Term 2. (0 Hours)
Offers dissertation supervision by members of the department.

Prerequisite(s): BIOE 9990 with a minimum grade of S

BIOE 9996. Dissertation Continuation. (0 Hours)
Offers continued dissertation work conducted under the supervision of a departmental faculty member.

Prerequisite(s): BIOE 9991 with a minimum grade of S or Dissertation Check with a score of REQ