Bioengineering (BIOE)

Course information contained within the Bulletin is accurate at the time of publication in June 2025 but is subject to change. For the most up-to-date course information, please refer to the Course Catalog.

BIOE 0844. The Bionic Human. 3 Credit Hours.
Can we replace our "worn-out" body parts with space-age materials? Will the day come when an injured athlete buys a tendon for the next big game? If so, who will have access, and when do we cease to be human? Become familiar with the extraordinary advances happening in bioengineering, including regenerative medicine, gene therapy, and mRNA vaccines, with the potential to cure diseases and create designer babies. Discuss science and pseudoscience: Goop, gurus, and the FDA, all the while getting a birds' eye view of the US and global health care systems. By the time you finish this course, you'll know how a pig heart could save your life, how stem cell research could affect your future, the purpose of animal testing, and whether we're going to have Iron Man suits any time soon. NOTE: This course fulfills a Science & Technology (GS) requirement for students under GenEd and Science & Technology Second Level (SB) for students under Core. Students cannot receive credit for this course if they have successfully completed BIOE 0944, MEE 0844, or MEE 0944.

Course Attributes: GS

Repeatability: This course may not be repeated for additional credits.

BIOE 0856. Ethical Issues in Biomedical Science, Engineering and Technology. 3 Credit Hours.
At some point in our lives, it is likely that each of us will be confronted with an ethical dilemma related to a biomedical technology. This course is designed to enable you to critically address important issues that arise as a result of advances in biomedical science, bioengineering and biotechnology. We will learn the science behind new technology such as genetic testing, gene editing, tissue engineering, human enhancement, artificial intelligence and medical imaging, with specific topics varying by semester. Challenging ethical questions will be considered using principles of ethical theories and frameworks, such as, is it ethical to create "designer babies", or what are the limits on what humans can do to enhance their performance? Material from peer-reviewed journal articles and reputable news sources will provide the basis for in-class discussions, scientific lectures, discussion boards, and structured debates. NOTE: This course fulfills a Science & Technology (GS) requirement for students under GenEd and Science & Technology Second Level (SB) for students under Core. Students cannot receive credit for this course if they have successfully completed BIOE 0956.

Course Attributes: GS

Repeatability: This course may not be repeated for additional credits.

BIOE 0944. Honors Bionic Human. 3 Credit Hours.
Can we replace our "worn-out" body parts with space-age materials? Will the day come when an injured athlete buys a tendon for the next big game? If so, who will have access, and when do we cease to be human? Become familiar with the extraordinary advances happening in bioengineering, including regenerative medicine, gene therapy, and mRNA vaccines, with the potential to cure diseases and create designer babies. Discuss science and pseudoscience: Goop, gurus, and the FDA, all the while getting a birds' eye view of the US and global health care systems. By the time you finish this course, you'll know how a pig heart could save your life, how stem cell research could affect your future, the purpose of animal testing, and whether we're going to have Iron Man suits any time soon. NOTE: This course fulfills a Science & Technology (GS) requirement for students under GenEd and Science & Technology Second Level (SB) for students under Core. Students cannot receive credit for this course if they have successfully completed BIOE 0844, MEE 0844, or MEE 0944.

Course Attributes: GS, HO

Repeatability: This course may not be repeated for additional credits.

BIOE 0956. Honors Ethical Issues in Biomedical Science, Engineering and Technology. 3 Credit Hours.
At some point in our lives, it is likely that each of us will be confronted with an ethical dilemma related to a biomedical technology. This course is designed to enable you to critically address important issues that arise as a result of advances in biomedical science, bioengineering and biotechnology. We will learn the science behind new technology such as genetic testing, gene editing, tissue engineering, human enhancement, artificial intelligence and medical imaging, with specific topics varying by semester. Challenging ethical questions will be considered using principles of ethical theories and frameworks, such as, is it ethical to create "designer babies", or what are the limits on what humans can do to enhance their performance? Material from peer-reviewed journal articles and reputable news sources will provide the basis for in-class discussions, scientific lectures, discussion boards, and structured debates. NOTE: This course fulfills a Science & Technology (GS) requirement for students under GenEd and Science & Technology Second Level (SB) for students under Core. Students cannot receive credit for this course if they have successfully completed BIOE 0856.

Course Attributes: GS, HO

Repeatability: This course may not be repeated for additional credits.

BIOE 2001. Frontiers in Bioengineering. 2 Credit Hours.
This survey course will provide a first introduction to the wide scope of biomedical engineering, with emphasis on the application of engineering principles to solving problems in biology and medicine. Specific topics will include biomechanics; bioimaging; bioinstrumentation and biomedical devices; artificial organs; computational biology and bioinformatics; biomaterials and drug delivery; cellular, tissue and regenerative engineering; and nanobiotechnology. At the end of this introductory course the students will be familiar with some of the major molecular, cellular, physiological and engineering principles that allow for problem solving in the vast area of biomedical engineering. Thus the students will be prepared to study in depth some of the specialized topics of bioengineering.

Repeatability: This course may not be repeated for additional credits.

BIOE 2101. Engineering Principles of Physiological Systems. 3 Credit Hours.
This course will introduce biomedical engineering students to quantitative modeling of physiological systems. It will cover fundamental topics in physiology ranging from cell membrane models and chemical messengers to neuronal signaling and control of body movement. In addition, specific physiological systems are discussed in detail, including the cardiovascular, pulmonary, and visual systems. Furthermore, pharmacokinetic models provide quantitative assessment of the dynamics of drug distribution and compartmental interactions. Hands-on laboratories combining actual experiments with computer simulations will reinforce the contents of classroom teaching.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (BIOL 2112 (may be taken concurrently), BIOL 1012 (may be taken concurrently), BIOL 2912 (may be taken concurrently), BIOL 1112 (may be taken concurrently), or 'Y' in BIOW)

BIOE 2201. Modeling Fundamentals in Bioengineering. 1.5 Credit Hour.
This course will introduce students to the fundamentals of modeling, design, and testing within SolidWorks computer aided design software with a focus on Bioengineering applications. Specifically, it will begin with methods of 3D design with an emphasis on iterative and parametric design mentality and design optimization. The course will conclude with a section of finite element analysis including the use of SolidWorks models for mechanical and fluid dynamic testing and analysis.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (MATH 1041, MATH 1941, MATH 1951, or 'Y' in METW) and (ENGR 1101, ENGR 1901, or 'Y' in ENGW)

BIOE 2202. Programming Fundamentals in Bioengineering. 1.5 Credit Hour.
This course will introduce students to programmatic methods and matrix algebra with specific applications in Bioengineering. Students will learn programming fundamentals such as loops and conditionals, as well as how to apply these methods to data analysis. In addition to the use of built-in Matlab functions, including those used for basic human interface, students will also learn to write their own functions and the methods to assemble complex programs.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (MATH 1041, MATH 1941, MATH 1951, or 'Y' in METW)

BIOE 2301. Quantitative Pathophysiology. 3 Credit Hours.
This course will introduce students to fundamental principles of human pathophysiology. Students will gain a systems level understanding of disease processes necessary for the rational design of novel therapeutic and diagnostic technologies. The course will integrate basic biological science and fundamental engineering principles in the evaluation of clinical disease manifestations. Topics that will be covered include: fundamental concepts of cellular homeostasis; cellular responses (adaptation, injury, cell death) induced by stress, injurious stimuli, and disease, and systemic models of major diseases within the US (cardiac, neoplastic, cerebrovascular, traumatic, neurodegenerative, diabetic, and pulmonary).

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 2101.

BIOE 2312. Mechanics for Bioengineering I. 4 Credit Hours.
This course will provide students with an understanding of the application of statics and strength of materials to biomechanical problem analyses. Topics will introduce basic concepts of mechanics and kinetic analyses with application to physiologic loading and motion in the body.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (PHYS 1062 (may be taken concurrently), PHYS 1962 (may be taken concurrently), PHYS 2022 (may be taken concurrently), or PHYS 2922 (may be taken concurrently)) and (MATH 1042, MATH 1942, 'Y' in MATW, or 'Y' in METW)

BIOE 2401. Biodesign - Needs and Ideation. 3 Credit Hours.
This course will incorporate the 5-steps of the Design Thinking process in a project-based learning (PBL) environment focusing on bioengineering-specific projects. During these open-ended projects, the students will work in small teams that will 1) delve deeply into the development of the problem statements and needs criteria, 2) ideation process, 3) designing potential solutions, 4) proof of concept, and 5) move on to designing and creating prototypes and writing up the supporting documentation.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (MATH 1042, 'Y' in MATW, or 'Y' in METW), (PHYS 1062 or PHYS 2022), and (ENGR 1101 or 'Y' in ENGW)

BIOE 3001. Research Design and Methods in Bioengineering. 2 Credit Hours.
In this course the upper division students will learn how to integrate fundamental principles of biology, chemistry, engineering, mathematics (including statistics) and physics to develop practical solutions for a variety of biomedical problems from cells to organisms. Students will use both engineering (methodology) and scientific (hypothesis) approaches to problem-solving thereby learning to distinguish between the two approaches. This course will teach the students the fundamental principles underlying modern measurements and control instrumentation utilized in science and engineering. Taking a quantitative and hands-on approach to measurement theory and practice, this course will present and analyze example instruments currently used in academic and industrial research. In addition, the students will consider and discuss bioethical issues involving biological and living systems. Specific bioethics topics that will be covered include stem cells, patents, conflict of interest, patient rights, animal rights, organ donation, and data manipulations but are not limited to them.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (MATH 1041, MATH 1941, MATH 1038, 'Y' in MATW, or 'Y' in METW) and (CHEM 1031 or CHEM 1951)

BIOE 3101. Bioelectrical Engineering Lab. 3 Credit Hours.
This laboratory class will introduce students to the empirical study of bioelectric phenomena in physiological systems. This includes the origin of biopotentials, the use of biopotential electrodes in their measurements and subsequent amplification, signal processing and analysis of their physiological relevance. Applications of physical principles and basic electric engineering techniques are emphasized.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 3201 (may be taken concurrently), (PHYS 1062 or PHYS 2022), (MATH 1042, MATH 1942, 'Y' in MATW, or 'Y' in METW), and BIOE 2001 (may be taken concurrently)

BIOE 3102. Biomaterials Lab. 3 Credit Hours.
This laboratory class will teach students experimental methods used to prepare and characterize biomaterials used in biomedical engineering. Students will learn basic techniques for the fabrication and characterization tools used for polymeric biomaterials, and investigate structure-property relationships as it applies to thermal, mechanical, surface and morphological properties of polymeric biomaterials.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 2101 (may be taken concurrently) and BIOE 3001.

BIOE 3201. Biomedical Instrumentation. 2 Credit Hours.
This course will introduce the upper division students to the fundamentals of medical instrumentation. Specifically, it will teach the physiological/physicochemical, biomechanical, computational and electronic principles governing the operation of select medical instrumentation. Focusing on classical and modern instrumentation used in specific clinical departments, such as cardiology, pulmonary medicine and critical care, radiology, and anesthesiology, the course will also introduce the students to the operation, safety aspects, and calibration of electronic, optical and acoustical instruments, as well as those involving ionizing radiation.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (PHYS 1062 or PHYS 2022) and (MATH 1042, MATH 1942, 'Y' in MATW, or 'Y' in METW)

BIOE 3301. Biomedical Signals and Systems. 3 Credit Hours.
This course will expose students to digital signal processing with emphasis on problems in biomedical research and clinical medicine. It covers principles and algorithms for processing signals and systems in both continuous and discrete time domains with examples from biomedical signal processing and control. Theory and practice of Continuous-time linear systems: convolution, steady-state responses, Fourier and Laplace transforms, transfer functions, poles and zeros, stability, sampling, feedback. Discrete-time linear systems: Z transform, filters, Fourier transform, signal processing. This class will make extensive use of Matlab projects.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (MATH 2101, ENGR 2011, or MEE 2011)

BIOE 3302. Drug Delivery. 3 Credit Hours.
This course will cover the engineering principles utilized in the design of drug delivery systems. Topics will include: drug delivery mechanisms (oral, parenteral, passive, targeted, etc.); therapeutic modalities and mechanisms of action; engineering principles of controlled release and quantitative understanding of drug transport (diffusion, convection); effects of electrostatics, macromolecular conformation, and molecular dynamics on interfacial interactions; thermodynamic principles of self-assembly; chemical and physical characteristics of delivery molecules and assemblies (polymer based, lipid based); significance of biodistributions and pharmacokinetic models; toxicity issues and immune responses.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (MATH 2041 (may be taken concurrently), MATH 2941 (may be taken concurrently), MATH 3041 (may be taken concurrently), MATH 3941 (may be taken concurrently), or 'Y' in METW)

BIOE 3303. Biotransport Phenomena. 3 Credit Hours.
This course will provide students with a quantitative understanding of mass (convection and diffusion) and momentum transport (viscous flow) in living systems, both at macroscopic and microscopic scales. We'll introduce differential equations to model and quantify aspects of bioengineering systems will be covered. Example systems will include the analysis of fluid flow phenomena in the cardiovascular, respiratory and other human organ systems, membrane transport, drug delivery and molecular transport.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in ENGR 3571, (MATH 2041 (may be taken concurrently), MATH 2941 (may be taken concurrently), MATH 3041 (may be taken concurrently), MATH 3941 (may be taken concurrently), or 'Y' in METW), and BIOE 2202 (may be taken concurrently)

BIOE 3312. Mechanics for Bioengineering II. 4 Credit Hours.
This course will provide students with an understanding of the application of mechanics of solids and dynamics to engineering problem analyses. Topics will introduce basic concepts of dynamics and mechanics with application to physiologic loading and motion in the body.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 2312.

BIOE 3331. Principles of Macromolecular Science. 3 Credit Hours.
In this course students will gain an understanding of the fundamentals of polymer physical chemistry. We will cover polymer structure and conformation, bulk and solution thermodynamics and phase behavior, polymer networks, and viscoelasticity. We will also apply engineering principles to the analysis of biomacromolecules, such as proteins, polysaccharides and oligonucleotides. Upon the completion of the course, students should be able to understand the influence of monomer structure, temperature, solution conditions, degree of polymerization and 3D conformation on the function of biopolymers.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (CHEM 1032 or CHEM 1952)

BIOE 3401. Biodesign - Testing and Validation. 3 Credit Hours.
This course aims to reinforce the Design Thinking concepts introduced earlier in the curriculum. Students will apply Design Thinking concepts to team projects. We will introduce topics in project management, machine shop use, computer modeling, ethical conduct of research and translational/entrepreneurial considerations, in addition to building upon the tools acquired and used in the Bioengineering Design I. The first part of the semester will be used for problem statement development and creations of several alternative design solutions. The second part of the semester will then be devoted to prototyping, testing and optimizing the proposed solutions, with oral presentations and written reports of their progress in the project throughout the semester.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (MATH 1042, 'Y' in MATW, or 'Y' in METW), (PHYS 1062 or PHYS 2022), and ENGR 1101.

BIOE 3402. Design Elective: Biodesign. 3 Credit Hours.
This course aims to reinforce the Design Thinking concepts introduced earlier in the curriculum. Students will apply Design Thinking concepts to team projects. We will introduce topics in project management, machine shop use, computer modeling, ethical conduct of research and translational/entrepreneurial considerations. This course will be an option for the required design elective used as a prerequisite for Senior Design 2 (ENGR 4296). The projects will start with problem statement development and creations of several alternative design solutions and move through prototyping, testing and optimizing the proposed solutions, with oral presentations and written reports of their progress in the project throughout the semester.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- (except where noted) in (MATH 1042 (C or higher), MATH 1942 (C or higher), or 'Y' in METW), ENGR 2196, BIOE 3201, BIOE 3101, BIOE 3001 (may be taken concurrently), and BIOE 3102 (may be taken concurrently)

BIOE 3511. Interactions of Biomaterials with Living Tissues. 3 Credit Hours.
This course will cover topics that illustrate how biomaterials interact with living tissues, focusing on cell culture, immunology, cell-biomaterial interfaces, and cell signaling. The students will learn the fundamentals maintaining living cells in culture and how these cells react to the presence of biomaterials using lecture and laboratory format.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 2101 and (CHEM 1031, CHEM 1035, or CHEM 1951)

BIOE 3719. Introduction to Bioengineering. 3 Credit Hours.
Course topics include biomaterials and implant materials, research proposal preparation, tyrosine-derived synthetic polymer devices for tissue engineering spine biomechanics, cellular material biomechanics, orthopedic biomechanics, hydroxyapatite/polymer composites, applications of injury biomechanics, biomechanics of the lower extremities, principles of polymers used in dental and biomaterials, interfaces in biomaterials. Students will be required to prepare a proposal for a design-oriented term project (i.e. rationale, concept and design, but no actual construction).

Repeatability: This course may not be repeated for additional credits.

BIOE 3725. Cell Biology for Engineers. 3 Credit Hours.
Cell Biology for Engineers is a basic course that introduces biological concepts in modern cellular and molecular biology to engineering students. Topics will include the chemical composition of cells, bioenergetics and metabolism, structure and function of the plasma membrane, transport across membranes, the cytoplasmic membrane system, the extracellular matrix, interactions between cells and their environment, the cytoskeleton and cell motility, sensory systems, and cell signaling. In addition, an introduction to basic anatomy and physiology of vertebrates will include the skeletal system, muscle system, cardiovascular system, and nervous system.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (CHEM 1031, CHEM 1035, or CHEM 1951)

BIOE 4101. Biomechanics Lab. 3 Credit Hours.
In this course students will apply principles of engineering mechanics in the design and utilization of biomechanical instrumentation. Principles of transduction, mechanics, sampling theory, strain, temperature, and flow measurement as applied to biomechanical systems will be covered. A background in data acquisition, electrical safety, operational amplifier and bridge circuits, and measurements is provided. Students will investigate the biomechanics of the musculoskeletal and cardiovascular systems in normal and pathological states.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 3101, BIOE 2201, and BIOE 2202.

BIOE 4182. Independent Study in Bioengineering. 1 to 5 Credit Hour.
Independent study course in bioengineering. Credits are arranged with instructor.

Repeatability: This course may be repeated for additional credit.

BIOE 4278. Cardiac Devices. 3 Credit Hours.
Intended for electrical engineering, biology, and bioengineering students. No course prerequisites. This course will cover cardiac anatomy and physiology, the heart's electrical system in health and disease, cardiac ECG rhythm interpretation, design and function of ECG monitoring devices, pacemakers and external and implanted defibrillators, and arrhythmia detection algorithms. The course will include observation of pacemaker implants, and troubleshooting in a pacemaker follow-up clinic. The course will prepare students to take the Heart Rhythm Society Allied Professional Pacemaker Certification examination. It is intended to put students in a competitive advantage for getting jobs in the expanding pacemaker and other medical electronics device industries.

Repeatability: This course may not be repeated for additional credits.

BIOE 4311. The Entrepreneurial Bioengineer. 3 Credit Hours.
Recognizing the increasingly entrepreneurial landscape of Bioengineering, this course will introduce the students to the fundamentals of entrepreneurship and is designed to provide students with a working knowledge of the modern entrepreneurial and business planning and the regulatory process with the special focus on translational development of bioengineering products from the bench to the bedside.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 2001 (may be taken concurrently)

BIOE 4333. Capstone Elective: Applied Biospectroscopy. 3 Credit Hours.
This course introduces the basics of light propagation in tissue and other turbid media, vibrational spectroscopy, absorption and fluorescence, and emerging spectroscopic applications. Emphasis is on applications for assessment of biomolecules, engineered tissues and clinically-relevant analyses including musculoskeletal disease and cancer diagnosis. Multivariate analyses for complex spectral data sets will also be introduced.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 2101, BIOE 3001, and BIOE 3101.

BIOE 4411. Capstone Elective: Biomaterials. 3 Credit Hours.
This course will focus on materials and design parameters used to develop human implant devices, bulk and surface characterization methods for biomaterials, biocompatibility, failure mechanisms of current biomaterials, and regulatory requirements for design and testing of human implant devices. Special attention will be given to biomaterials used in tissue regeneration, orthopedics, and controlled drug delivery.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 2101.

BIOE 4421. Capstone Elective: Bionanotechnology. 3 Credit Hours.
This course is intended for upper division students interested in acquiring knowledge involving nanometer-sized objects frequently utilized within the biomedical sciences and engineering areas. The aim of the class is to introduce fundamental concepts critical in the design, preparation, analysis, and usage of bionanotechnology (or nanobiotechnology) and its multiple bottom-up and top-down approaches. Multiple nanomaterials categories, such as nanoparticles, nanotubes, biomacromolecules, synthetic polymers, and self-assembled structures, will be covered in detail along with their applications.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in CHEM 2201 and BIOE 1301.

BIOE 4431. Capstone Elective: Neuroengineering. 3 Credit Hours.
This course will teach students how signals are generated and propagated in neurons and neuronal circuits, and how this knowledge can be utilized to engineer devices to assist people with neurologic disease or injury. The functions of neurons as discrete elements and as parts of neuronal assemblies will be examined; generator and action potentials; conduction in nerve fibers and across synaptic junctions; analysis of sensory and neuromuscular systems; EEG and EKG waveforms. At the completion of the course, students will have gained a fundamental understanding of neural interface/prosthetics design parameters from basic neural physiology to models of neural mechanisms. We will also review advanced neural interfaces currently being developed and or produced commercially by the field.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 2101 and (MATH 2041 (may be taken concurrently), MATH 2941 (may be taken concurrently), MATH 3041 (may be taken concurrently), MATH 3941 (may be taken concurrently), or 'Y' in METW)

BIOE 4441. Capstone Elective: Biomechanics. 3 Credit Hours.
This course will provide an integrative and multi-scale understanding of biomechanics that spans from tissues, to organs, to the dynamics of an intact, running body. Foundational topics will include muscle mechanics, skeletal mechanics, gait and whole body dynamics. The course will then move on to cover selected topics at the forefront of applied biomechanics including clinical biomechanics and the design and optimization of prosthetic limbs. Finally, frontiers in neural-interfacing for prostheses and rehabilitation, including optogenetics and other emerging areas affecting biomechanics, including robotics and robotic exoskeletons, will be covered.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (BIOE 2101 or BIOE 3725) and (BIOE 3312 or (ENGR 2332 and ENGR 2333))

BIOE 4451. Capstone Elective: Biomedical Imaging. 3 Credit Hours.
In this course students learn how light, X-rays, radiopharmaceuticals, ultrasound, magnetic fields, and other energy probes are generated and how they interact with tissues and detectors to produce useful image contrast. Practical issues such as beam generation, dose limitations, patient motion, spatial resolution and dynamic range limitations, and cost-effectiveness will be addressed. Emphasis will be placed on diagnostic radiological imaging physics, including the planar X-ray, digital subtraction angiography mammography, computed tomography, nuclear medicine, ultrasound, and magnetic resonance imaging modalities.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in PHYS 1062, (CHEM 1031, CHEM 1035, or CHEM 1951), (BIOL 1111, BIOL 1012, BIOL 2112, BIOL 1911, BIOL 2912, or 'Y' in BIOW), and (MATH 2041, MATH 2941, MATH 3041, MATH 3941, or 'Y' in METW)

BIOE 4461. Capstone Elective: Principles of Tissue Engineering. 3 Credit Hours.
This course will introduce fundamental concepts of tissue engineering and regenerative medicine, focusing on biomaterials used for scaffolds, mechanisms of cell-biomaterial interactions, biocompatibility and foreign body response, cellular engineering, and tissue biomechanics. Principles of cell/developmental and stem cell biology will be introduced, which will enable the students to apply a multidisciplinary approach to engineering select tissues and organs, such as the musculoskeletal system, cardiovascular tissues, the nervous system, and to design artificial organs. These topics will also be discussed in the context of scale-up, manufacturing, ethical and regulatory concerns. Note: Prior to fall 2017, the course title was "Capstone Elective: Principles of Tissue and Regenerative Engineering."

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 2101.

BIOE 4471. Mechanobiology. 3 Credit Hours.
Mechanobiology is an emerging interdisciplinary field that focuses on the role of mechanical cues in governing cellular behavior. This course will address the means by which a cell utilizes its adhesions to neighboring cells and to the surrounding extracellular matrix to sense external forces and furthermore, how these forces are transduced within the cell to alter cellular behavior and regulate tissue architecture. This course will also discuss how the extracellular matrix influences cellular behavior during development, health, and disease. Furthermore, this course will also discuss the various tools and techniques developed that pushed the field of mechanobiology forward.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (BIOL 1012, BIOL 1112, BIOL 1912, BIOL 2112, or BIOL 2912), BIOE 3001, and (BIOE 2312 or BIOE 4101)

BIOE 4500. Special Topics in Bioengineering. 3 Credit Hours.
An emerging or advanced area of bioengineering research will be covered. Topics vary by semester.

Repeatability: This course may be repeated for additional credit.

BIOE 4501. Capstone Elective: Regenerative Engineering. 3 Credit Hours.
This course is a continuation of fundamental concepts introduced in Principles of Tissue and Regenerative Engineering focusing on developmental biology used in tissue engineering and regenerative medicine. Principles of cell development/biology, cell-cell interactions, signal transduction, and stem cell biology will be discussed with applications to regenerative medicine. These topics will also be discussed in the context of scale-up, manufacturing, ethical and regulatory concerns.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in BIOE 2101 and (CHEM 2202 or CHEM 2922)

BIOE 4555. Capstone Elective - Biophotonics: Seeing is Believing. 3 Credit Hours.
Only a small portion of the world around us is visible to the human eye. With revolutionary microscopy developments there are ways to visualize drug effects, forces, viral infection, or cancer metastasis, and use light to control biological processes. Once we see biology happen, the result is not just a pretty image. We can use machine learning and artificial intelligence (AI) to improve resolution and quantify the imaging data. In this course students will learn how light can be used to visualize and manipulate biomaterials at molecular, cellular and tissue scale. The first part of the course will provide a review of light and optics. We will cover typical hardware used for imaging in biology, such as light sources, objectives and detectors used to generate images. The second part of the course will include hands-on fluorescent microscopy, the main tool for imaging in life sciences, and it will include imaging of cell cultures in 2D and 3D and tissue sections. We will use typical image processing tools, including Fiji, Matlab and selected Python plugins, and learn how to implement AI tools to improve images and imaging data. Final sessions will include presentations on specialized techniques by students.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (PHYS 1062 or PHYS 2022), CHEM 2202, and (BIOL 1012, BIOL 1112, BIOL 2112, BIOL 2912, or BIOE 3102 (may be taken concurrently))

BIOE 4741. Biomaterials for Engineers. 3 Credit Hours.
This course introduces engineering students to materials as they interact with biological systems, primarily in medicine. Topics will include a review of properties of materials, the classes of materials, tissues that come into contact with materials, the degradation of materials in the biological environment, the application of materials for specific uses, tissue engineering, and biomaterials standards and regulations.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C- in (CHEM 1031, CHEM 1035, or CHEM 1951)

BIOE 5278. Cardiac Devices. 3 Credit Hours.
This course will describe the structure, function and control of the cardiovascular system and its quantitative modeling. We will cover the functional organization of main elements within cardiovascular system including and interfacing systems, such as renal and respiratory systems. We will go through the major electrical signals, neurological and endocrine controls, which regulate function of the cardiovascular systems. Students will learn about pacing signals generated naturally in the heart and synthesized by electronics. Design considerations and indications for use of various devices to directly or indirectly affect heart function.

Repeatability: This course may not be repeated for additional credits.

BIOE 5301. Biosignals. 3 Credit Hours.
This course offers a deep overview of the signals in the Biomedical fields. Signals are studied in several modalities, including time frame, frequency frame, and statistical frame. A deep analysis of filters and analysis tools is included together with some basic techniques of storing and pattern interpretation techniques. Furthermore, the course gives to the student the necessary knowledge to realize a complete Data Acquisition, Analysis and Logging using LabView as a tool. The laboratory activities include the development of a complete system to do acquisition, analysis, report and logging of data incoming from sensors.

Repeatability: This course may not be repeated for additional credits.

BIOE 5311. The Entrepreneurial Bioengineer. 3 Credit Hours.
This course provides a practical overview of all stages of development of medical devices in regenerative medicine, from idea to launch of a company and commercialization of the product into international markets to address unmet medical needs. We will review the initial idea, based on an unmet medical need, review issues of intellectual property creation, determination of target markets, pre-clinical and clinical development, and different regulatory pathways leading to product approval and market introduction. We will discuss issues of company formation, financing and management, as well as target markets and avenues towards revenue generation. Note: Prior to fall 2017, the course title was "Entrepreneurial Studies in Regenerative Medicine - From Idea to Medical Practice".

Repeatability: This course may not be repeated for additional credits.

BIOE 5321. Biosensors. 3 Credit Hours.
This course offers an in-depth overview of several sensors used in the Biomedical Fields. The sensors are analyzed from an engineering point of view going from the physical principles to the necessary filtering and linearization studying the characteristics of output signals. The course also gives the student the necessary basis for Data Acquisition using LabView as a tool. The laboratory activities include the connection of sensors, the study of amplification, linearization and interpretation of data.

Repeatability: This course may not be repeated for additional credits.

BIOE 5333. Applied Biospectroscopy. 3 Credit Hours.
This course introduces the basics of light propagation in tissue and other turbid media, vibrational spectroscopy, absorption and fluorescence, and emerging spectroscopic applications. Emphasis is on applications for assessment of biomolecules, engineered tissues and clinically-relevant analyses including musculoskeletal disease and cancer diagnosis. Multivariate analyses for complex spectral data sets will also be introduced.

Repeatability: This course may not be repeated for additional credits.

BIOE 5421. Capstone Elective: Bionanotechnology. 3 Credit Hours.
This course is intended for graduate students interested in acquiring knowledge involving nanometer-sized objects frequently utilized within the biomedical sciences and engineering areas. The aim of the class is to introduce fundamental concepts critical in the design, preparation, analysis, and usage of bionanotechnology (or nanobiotechnology) and its multiple bottom-up and top-down approaches. Multiple nanomaterials categories, such as nanoparticles, nanotubes, biomacromolecules, synthetic polymers, and self-assembled structures, will be covered in detail along with their applications.

Repeatability: This course may not be repeated for additional credits.

BIOE 5431. Neuroengineering. 3 Credit Hours.
This course will teach students how signals are generated and propagated in neurons and neuronal circuits, and how this knowledge can be utilized to engineer devices to assist people with neurologic disease or injury. The functions of neurons as discrete elements and as parts of neuronal assembles will be examined; generator and action potentials; conduction in nerve fibers and across synaptic junctions; analysis of sensory and neuromuscular systems; EEG and EKG waveforms. At the completion of the course, students will have gained a fundamental understanding of neural interface/prosthetics design parameters from basic neural physiology to models of neural mechanisms. We will also review advanced neural interfaces currently being developed. The course will end with coverage of selected frontiers of neuroscience, including neurogenetic techniques, viral methods, and optogenetics.

Repeatability: This course may not be repeated for additional credits.

BIOE 5441. Biomechanics. 3 Credit Hours.
This course will provide an integrative and multi-scale understanding of biomechanics that spans from tissues, to organs, to the dynamics of an intact, running body. Foundational topics will include muscle mechanics, skeletal mechanics, gait and whole body dynamics. The course will then move on to cover selected topics at the forefront of applied biomechanics including clinical biomechanics and the design and optimization of prosthetic limbs. Finally, frontiers in neural-interfacing for prostheses and rehabilitation, including optogenetics and other emerging areas affecting biomechanics, including robotics and robotic exoskeletons, will be covered.

Repeatability: This course may not be repeated for additional credits.

BIOE 5451. Biomedical Imaging. 3 Credit Hours.
This course focuses on principles of diagnostic radiological imaging physics, including X-ray, computed tomography, and nuclear medicine, as well as optical imaging, ultrasound and magnetic resonance imaging modalities. The interaction of these modalities with tissues and detectors to produce useful image contrast will be presented, and students will gain an understanding of the basic physics of image acquisition and algorithms for image generation. Signal and noise characteristics, image quality and image reconstruction algorithms will also be covered. Image processing through MATLAB programming will be covered in class and in assignments.

Repeatability: This course may not be repeated for additional credits.

BIOE 5461. Principles of Tissue Engineering. 3 Credit Hours.
This course will introduce fundamental concepts of tissue engineering and regenerative medicine, focusing biomaterials used for scaffolds, mechanisms of cell-biomaterial interactions, biocompatibility and foreign body response, cellular engineering, and tissue biomechanics. Principles of cell/developmental and stem cell biology will be introduced, which will enable the students to apply a multidisciplinary approach to engineering select tissues and organs, such as the musculoskeletal system, cardiovascular tissues, the nervous system, and to design artificial organs. These topics will also be discussed in the context of scale-up, manufacturing, ethical and regulatory concerns. Note: Prior to fall 2017, the course title was "Principles of Tissue and Regenerative Engineering."

Repeatability: This course may not be repeated for additional credits.

BIOE 5471. Mechanobiology. 3 Credit Hours.
Mechanobiology is an emerging interdisciplinary field that focuses on the role of mechanical cues in governing cellular behavior. This course will address how a cell utilizes its adhesions to neighboring cells and to the surrounding extracellular matrix to sense external forces and furthermore, how these forces are transduced within the cell to alter cellular behavior and regulate tissue architecture. This course will also discuss how the extracellular matrix influences cellular behavior during development, health, and disease. Additionally, this course will also discuss the various tools and techniques developed to probe cytoskeletal structures, molecular motors, plasma membranes, cellular adhesion structures, and matrix proteins that pushed the field of mechanobiology forward. This course will culminate in integrating all new foundational knowledge in mechanobiology to propose new studies manipulating molecular, cellular, or tissue-level behavior for applications in diverse fields such as regenerative engineering, wound healing, or cancer diagnostics.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of B- in BIOE 5721 (may be taken concurrently)

BIOE 5500. Special Topics in Bioengineering. 3 Credit Hours.
An emerging or advanced area of bioengineering research will be covered. Topics vary by semester.

Repeatability: This course may be repeated for additional credit.

BIOE 5501. Regenerative Engineering. 3 Credit Hours.
This course is a continuation of fundamental concepts introduced in Principles of Tissue and Regenerative Engineering focusing on developmental biology used in tissue engineering and regenerative medicine. Principles of cell development/biology, cell-cell interactions, signal transduction, and stem cell biology will be discussed with applications to regenerative medicine. These topics will also be discussed in the context of scale-up, manufacturing, ethical and regulatory concerns.

Repeatability: This course may not be repeated for additional credits.

BIOE 5555. Biophotonics: Seeing is Believing. 3 Credit Hours.
Only a small portion of the world around us is visible to the human eye. With revolutionary microscopy developments, nowadays there are ways to visualize drug effects, forces, viral infection or cancer metastasis, or use light to control biological processes. Once we see biology happen, the result is not just a pretty image. We can use machine learning and artificial intelligence (AI) to improve resolution and quantify the imaging data. In this course students will learn how light can be used to visualize and manipulate biomaterials at molecular, cellular and tissue scale. The first part of the course will provide a review of light and optics. We will cover typical hardware used for imaging in biology, such as light sources, objectives and detectors used to generate images. The second part of the course will include hands-on fluorescent microscopy, the main tool for imaging in life sciences, and it will include imaging of cell cultures in 2D and 3D and tissue sections. We will use typical image processing tools, including Fiji, Matlab and selected Python plugins, and learn how to implement AI tools to improve images and imaging data. Final sessions will include presentations on specialized techniques by students.

Repeatability: This course may not be repeated for additional credits.

BIOE 5600. Bioengineering Graduate Seminar. 0 Credit Hours.
Required seminar for bioengineering graduate students. These seminars include speakers from academic and professional backgrounds for both scientific development and professional development. Students will be graded on participation of at least 70% of the bi-weekly seminars throughout the duration of the semester.

Repeatability: This course may be repeated for additional credit.

BIOE 5719. Introduction to Bioengineering. 3 Credit Hours.
This course offers an introduction to biomedical engineering, a diverse and evolving field that integrates engineering principles, life sciences, clinical medicine, research and engineering design, with the overall goal of improving health care and quality of life. Professors with expertise in specific fields of biomedical engineering will present lectures and discussions on a broad range of topics, including tissue engineering and regenerative medicine, biomaterials, biomechanics, bioinstrumentation, biomedical imaging and optics, and signal processing.

Repeatability: This course may not be repeated for additional credits.

BIOE 5721. Cell Biology for Engineers. 3 Credit Hours.
This course introduces biological concepts in modern cellular and molecular biology to engineering students. Topics will include the chemical composition of cells, bioenergetics and metabolism, structure and function of the plasma membrane, transport across membranes, the cytoplasmic membrane system, the extracellular matrix, interactions between cells and their environment, the cytoskeleton and cell motility, sensory systems, and cell signaling. In addition, an introduction to basic anatomy and physiology of vertebrates will include the skeletal system, muscle system, cardiovascular system, and nervous system.

Repeatability: This course may not be repeated for additional credits.

BIOE 5737. Systems Physiology for Engineers. 3 Credit Hours.
Systems Physiology is designed for graduate students majoring in engineering and for others interested in studying physiological processes from the molecular level to the organ/systems level. Among the topics covered are: scaling, respiration, circulation, cardiac process, renal function, muscle function, neuromuscular junction, neural processes, and temperature regulation. The course stresses the application of energetic and informational principles to the study of the body.

Repeatability: This course may not be repeated for additional credits.

BIOE 5741. Biomaterials for Engineers. 3 Credit Hours.
This course introduces engineering students to materials as they interact with biological systems, primarily in medicine. Topics will include a review of properties of materials, the classes of materials, tissues that come into contact with materials, the degradation of materials in the biological environment, the application of materials for specific uses, tissue engineering, and biomaterials standards and regulations.

Repeatability: This course may not be repeated for additional credits.

BIOE 5999. Research Experience in Bioengineering. 0 Credit Hours.
Research Experience provides graduate students laboratory experiences/research practices prior to undertaking independent, directed, master project, master's thesis, or dissertation research. This course allows graduate students the opportunity to learn to use laboratory equipment, designing and carrying out an experiment(s), collecting preliminary data, field experiences, and participation in laboratory meeting, etc. with faculty which may lead to identifying a faculty mentor. The course will be graded as Pass or Fail. The Research Experience is a non-repeatable course. After the completion of this Research Experience course, students will need to be enrolled in independent study, directed research, master's research, master's thesis, dissertation proposal, or dissertation if they continue in an active research program.

Repeatability: This course may not be repeated for additional credits.

BIOE 9182. Independent Study. 1 to 6 Credit Hour.
Repeatability: This course may be repeated for additional credit.

BIOE 9282. Independent Study II. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by Ph.D. students.

Repeatability: This course may be repeated for additional credit.

BIOE 9991. Directed Research. 1 to 6 Credit Hour.
Under the guidance of a faculty member, the student will conduct independent research on a selected topic in bioengineering.

Repeatability: This course may be repeated for additional credit.

BIOE 9994. BioEngineering Preliminary Examination Preparation. 1 to 6 Credit Hour.
Repeatability: This course may be repeated for additional credit.

BIOE 9995. BioEngineering Project Research. 1 to 6 Credit Hour.
Repeatability: This course may be repeated for additional credit.

BIOE 9996. BioEngineering Thesis Research. 1 to 6 Credit Hour.
Repeatability: This course may be repeated for additional credit.

BIOE 9998. Bioengineering Pre-Dissertation Research. 1 to 6 Credit Hour.
Repeatability: This course may be repeated for additional credit.

BIOE 9999. BioEngineering Dissertation Research. 1 to 6 Credit Hour.
Repeatability: This course may be repeated for additional credit.