

BIOMEDICAL ENGINEERING (BME)

BME 100

Introduction to the Profession

Introduces the student to the scope of the biomedical engineering profession and its role in society, and develops a sense of professionalism in the student. Provides an overview of biomedical engineering through lectures, presentations by outside speakers, hands-on exercises, and scientific literature analyses. Develops professional communication and teamwork skills.

Lecture: 1 **Lab:** 2 **Credits:** 2

Satisfies: Communications (C)

BME 200

Biomedical Engineering Computer Applications

In this course, students will apply programming to solve quantitative biomedical engineering problems across cell/tissue engineering, neural engineering, and medical imaging. Students will also be exposed to additional engineering and product development programming tools and environments.

Prerequisite(s): MATH 252* and CS 104, An asterisk (*) designates a course which may be taken concurrently.

Lecture: 1 **Lab:** 2 **Credits:** 2

BME 301

Bio-Fluid Mechanics

Basic properties of fluids in motion. Lagrangian and Eulerian viewpoints, material derivative, streamlines. Continuity, energy, angular and linear momentum equations in integral and differential forms. Applications in biofluids and biomedical devices; rheology of biological fluids.

Corequisite(s): BME 320

Prerequisite(s): BIOL 115 and MATH 251 and MMAE 202

Lecture: 3 **Lab:** 0 **Credits:** 3

BME 309

Biomedical Imaging

An introduction to biomedical imaging concepts and modalities. Topics covered include general principles of image science (image quality, sampling, etc.), X-ray-based imaging [conventional x-ray imaging, mammography, computed tomography (CT), and digital subtraction angiography (DSA)], and nuclear medicine [gamma camera, single photon emission computed tomography (SPECT), and positron emission tomography (PET)].

Prerequisite(s): (BME 330* or ECE 308*) and PHYS 221, An asterisk (*) designates a course which may be taken concurrently.

Lecture: 3 **Lab:** 0 **Credits:** 3

BME 310

Biomaterials

Applications of biomaterials in different tissue and organ systems. Relationship between physical and chemical structure of materials and biological system response. Choosing, fabricating, and modifying materials for specific biomedical applications.

Prerequisite(s): CHEM 125 and PHYS 123

Lecture: 3 **Lab:** 0 **Credits:** 3

Satisfies: Communications (C)

BME 315

Instrumentation and Measurement Laboratory

Laboratory exercises stress instrumentation usage and data analysis used to determine physiological functions and variables and the relations to the physiological variability.

Prerequisite(s): ECE 211*, An asterisk (*) designates a course which may be taken concurrently.

Lecture: 0 **Lab:** 3 **Credits:** 2

BME 320

Fluids Laboratory

Laboratory experiments in thermodynamics, biological fluid flow, and heat transfer. Emphasis is placed on current methods, instrumentation, and equipment used in biomedical engineering; oral presentation of results; and on the writing of comprehensive reports. Open only to Biomedical Engineering majors.

Corequisite(s): BME 301

Prerequisite(s): BIOL 117 and BME 315

Lecture: 0 **Lab:** 3 **Credits:** 1

Satisfies: Communications (C)

BME 325

Bioelectronics Laboratory

Practical hands on design, construction and testing of electric and electronic circuitry for biomedical applications. Basic concepts will be presented with emphasis on their relevance to the design of systems that can be used for clinical and basic scientific research.

Prerequisite(s): ECE 213* and BME 315, An asterisk (*) designates a course which may be taken concurrently.

Lecture: 0 **Lab:** 3 **Credits:** 1

BME 330

Analysis of Biosignals and Systems

This course is a junior level introduction to the theoretical and practical aspects of signal processing and dynamic systems behavior as they relate to physiological, biological, and biomedical systems. The topics covered will include sampling theory, continuous and discrete Fourier transforms and series, Laplace transforms, Linear systems theory, signal filtering, models of biological and physiological systems, and analysis of dynamic and feedback systems.

Prerequisite(s): ECE 211 and MATH 252

Lecture: 3 **Lab:** 0 **Credits:** 3

BME 331

Modeling and Control of Biological Systems

The course expands upon the systems and signal processing concepts introduced in BME 330 to develop the tools to model physiological processes and the feedback control of these processes.

Prerequisite(s): (BME 330 or ECE 308) and BME 422

Lecture: 3 **Lab:** 0 **Credits:** 3

BME 335**Thermodynamics of Living Systems**

Principles of thermodynamics and conservation of mass applied to living systems and biomedical devices. The first and second laws of thermodynamics, pHs and chemical equilibrium, metabolic stoichiometry and energetics.

Prerequisite(s): MATH 251 and CHE 202

Lecture: 3 Lab: 0 Credits: 3

BME 402**Introduction to Regulatory Science for Engineers**

Engineers must be equipped to answer the growing demands for new medical technologies. Introduction to Regulatory Science teaches engineers how the regulated environment impacts the design, testing, and delivery of medical devices. It will equip students with the essential skills and tools critical to the practice of engineering in the medical device industry. In this course, students will be exposed to the core concepts, processes, and tools surrounding the global medical device regulatory framework, and will gain foundational knowledge for the practical application of regulations throughout the product development lifecycle. From knowledge gained in the class, students will be expected to work in teams and use critical thinking, data analysis and interpretation skills to research, evaluate, and present a scientific, technical, and legally justifiable approach for the global introduction of a new medical device.

Lecture: 3 Lab: 0 Credits: 3

BME 405**Physiology Laboratory**

A laboratory course which demonstrates basic concepts of bioengineering design through experimental procedures involving humans and experimental animals. Statistical principles of experimental design. Study of possible errors. Experiments include nerve action, electrocardiography, mechanics of muscle, membranes, and noninvasive diagnostics in humans. Open only to Biomedical Engineering majors.

Corequisite(s): BME 453

Prerequisite(s): BME 315

Lecture: 0 Lab: 3 Credits: 2

BME 417**Technologies for Treatment of Diabetes**

Study of physiological control systems and engineering of external control of biological systems by focusing on an endocrine system disorder – diabetes. The effects of type 1 diabetes on glucose homeostasis and various treatment technologies for regulation of glucose concentration. Development of mathematical models describing the dynamics of glucose and insulin concentration variations, blood glucose concentration measurement and inference techniques, insulin pumps, and artificial pancreas systems.

Lecture: 3 Lab: 0 Credits: 3

BME 418**Reaction Kinetics for BME**

This course focuses on analysis of rate data and single and multiple reaction schemes. Biomedical topics include biological systems, enzymatic pathways, enzyme and receptor-ligand kinetics, pharmacokinetics, heterogeneous reactions, microbial cell growth and product formation, and the design and analysis of biological reactors.

Prerequisite(s): BME 335 and MATH 252

Lecture: 3 Lab: 0 Credits: 3

BME 419**Introduction to Design Concepts in Biomedical Engineering**

Introduction to Design Concepts in Biomedical Engineering. This course aims to educate students on project definition, and on the design, development and technology transfer of potential biomedical products in the context of the student's major capstone project. Students will learn best practices for designing a marketable medical device, including the design process from the clinical problem definition through prototype and clinical testing to market readiness.

Prerequisite(s): BME 320 or BME 325

Lecture: 2 Lab: 0 Credits: 2

Satisfies: Communications (C)

BME 420**Design Concepts in Biomedical Engineering**

An introduction to the strategies and fundamental bioengineering design criteria behind the development of biomedical engineering systems and implantable devices that use either synthetic materials or hybrid (biological-synthetic) systems. Analysis and design of replacements for the heart, kidneys, and lungs. Specification and realization of structures for artificial organ systems. Students will be required to complete a team-oriented design project in their chosen track.

Prerequisite(s): BME 419

Lecture: 3 Lab: 0 Credits: 3

Satisfies: Communications (C)

BME 422**Mathematical Methods for Biomedical Engineers**

This course integrates mathematical and computational tools that address directly the needs of biomedical engineers. The topics covered include the mathematics of diffusion, pharmacokinetic models, biological fluid mechanics, and biosignal representations and analysis. The use of MATLAB will be emphasized for numerically solving problems of practical relevance.

Prerequisite(s): ((MATH 252 and CS 104) or Graduate standing) and (BME 330* or ECE 308*), An asterisk (*) designates a course which may be taken concurrently.

Lecture: 3 Lab: 0 Credits: 3

BME 423**Cell Biomechanics: Principles and Biological Processes**

This course will provide students an opportunity to learn about mechanical forces that develop in the human body and how they can influence cell functions in a range of biological processes from embryogenesis, wound healing, and regenerative medicine to pathological conditions such as cancer invasion. Examples of research methods for investigating cell biomechanics in various biological systems will be discussed.

Prerequisite(s): BME 301

Lecture: 3 **Lab:** 0 **Credits:** 3

BME 424**Quantitative Aspects of Cell and Tissue Engineering**

This course is designed to cover fundamentals of cell and tissue engineering from a quantitative perspective. Topics addressed include elements of tissue development, cell growth and differentiation, cell adhesion, migration, molecular and cellular transport in tissues and polymeric hydrogels for tissue engineering and drug delivery applications.

Prerequisite(s): BME 482 and BME 418

Lecture: 3 **Lab:** 0 **Credits:** 3

BME 425**Introduction to Medical Devices, BioMEMS and Microfluidics**

This course will present fundamentals and applications of medical devices, BioMEMS, and microfluidic technologies for applications in the broad health and biomedical engineering. It will provide a broad view of the general field and a knowledge of relevant fabrication methods and analysis techniques. Fabrication and analytical techniques, interfacing with biological materials, and techniques for analyte detection will be emphasized. The course will include individual projects and critical paper reviews in which each student will be encouraged to master basic concepts in design and fabrication for devices for specific applications.

Lecture: 3 **Lab:** 0 **Credits:** 3

BME 427**Extracellular Matrix Biology**

The Extra Cellular Matrix (ECM) is that which connects cells in tissues and provides much of the organization and support in almost every tissue and or organ system of the body. Thus the aim of this course is to give students insights into ECM biology and its relevance to modern medicine and biomedical (tissue) engineering. A significant portion of working population is suffering from ECM-related maladies, and the focus of research has shifted into creating ECM implants. The ECM implant market is growing rapidly. For instance, the collagen meniscus implant market was reported to be at \$308.6 million in 2018. Understanding the implications of the molecular biology of ECM to feed into this research is highly relevant for students considering careers (academic and industry) in life sciences in industry, academia and healthcare. Extracellular Matrix (ECM) is a highly complex system in mammalian biology responsible for structural support and functional (biochemical) signals for physiology. Specific amino acid sequences on the various ECM elements are responsible to trigger intra- and extracellular cascades leading to cell division, proliferation, tissue regeneration, wound healing and inflammation. This course will focus on the following key concepts: a) Gene expression, structure and function of various ECM proteins and complexes and the physiological processes. b) Etiology and the molecular progression of diseases caused by abnormalities to ECM proteins. c) Mechanobiology of various ECM proteins. d) Structure function and mechanical function of ECM interfaces with other tissues (muscle, bone, skin etc.) e) Implications for tissue engineering and development of novel biomimetic and biological ECM implants.

Lecture: 750 **Lab:** 0 **Credits:** 3

BME 428**Engineering World Health**

This course covers the major types of medical equipment, including the principles of operation, the physiology underlying the measurement, the major functional (system) pieces for each instrument, and typical problems/applications of each instrument. Special focus is placed on making reliable and safe repairs in a low resource setting: Troubleshooting, creative problem solving, calibration and testing. Laboratory sessions will focus on learning hands on and technical knowledge required for completing basic electronic and mechanical repairs. Basic electronics through simple power supply design will be covered. Over the course of the semester, the class will travel to a hospital or training laboratory to troubleshoot and repair medical equipment as a group.

Prerequisite(s): MATH 152 and PHYS 221

Lecture: 3 **Lab:** 0 **Credits:** 3

BME 431**Modern Optics and Lasers**

This is an undergraduate course covering the basics of optics and modern aspects of the field such as lasers and nonlinear optics. Connections to other fields such as acoustics, microwaves, electron-beam optics, quantum mechanics will be pointed out. The theory will be supplemented with demonstration experiments of optical phenomena. Practical problems will be discussed such as the design of an optical imaging system or precision interferometry.

Prerequisite(s): PHYS 221 or Graduate standing

Lecture: 3 **Lab:** 0 **Credits:** 3

BME 433**Biomedical Engineering Applications of Statistics**

Application of modern computing methods to the statistical analysis of biomedical data. Sampling, estimation, analysis of variance, and the principles of experimental design and clinical trials are emphasized.

Prerequisite(s): MATH 251

Lecture: 3 Lab: 0 Credits: 3

BME 437**Introduction to Molecular Imaging**

This course provides an overview of molecular imaging, a subcategory of medical imaging that focuses on noninvasively imaging molecular pathways in living organisms. Topics include imaging systems, contrast agents, reporter genes and proteins, tracer kinetic modeling. Preclinical and clinical applications will also be discussed with an emphasis on cancer and the central nervous system.

Prerequisite(s): BME 422

Lecture: 3 Lab: 0 Credits: 3

BME 438**Neuroimaging**

This course describes the use of different imaging modalities to study brain function and connectivity. The first part of the course deals with brain function. It includes an introduction to energy metabolism in the brain, cerebral blood flow, and brain activation. It continues with an introduction to magnetic resonance imaging (MRI), perfusion-based fMRI, BOLD fMRI, fMRI paradigm design and statistical analysis, introduction to positron emission tomography (PET) and studying brain function with PET, introduction to magneto encephalography and studying brain function with (MEG). The second part of the course deals with brain connectivity. It includes an introduction to diffusion tensor MRI, explanation to the relationship between the diffusion properties of tissue and its structural characteristics, white matter fiber tractography.

Prerequisite(s): PHYS 221

Lecture: 3 Lab: 0 Credits: 3

BME 439**Advanced Medical Imaging**

This course introduces advanced clinical imaging modalities, research imaging techniques, and concepts from image science and image perception. The first part of the course introduces the perception of image data by human observers and the visualization of brain structure and function. It includes an introduction to magnetic resonance imaging (MRI) and a survey of neurological imaging via functional MRI (fMRI). The second part of the course covers image science, clinical imaging applications, and novel research imaging techniques. It includes an introduction to radiation detection and image quality evaluation, a survey of clinical cases, and an overview of new imaging methods.

Prerequisite(s): BME 309

Lecture: 3 Lab: 0 Credits: 3

BME 443**Biomedical Instrumentation and Electronics**

Principles of circuit analysis are applied to typical transducer and signal recording situations found in biomedical engineering.

Prerequisite(s): (BME 315 and ECE 211) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

BME 445**Quantitative Neural Function**

Computational approach to basic neural modeling and function, including cable theory, ion channels, presynaptic potentials, stimulation thresholds, and nerve blocking techniques. Synaptic function is examined at the fundamental level.

Prerequisite(s): BME 453

Lecture: 3 Lab: 0 Credits: 3

BME 450**Animal Physiology**

Respiration; circulation; energy metabolism; temperature regulation; water and osmotic regulation; digestion and excretion; muscle and movement; nerve excitation; information control and integration; chemical messengers. Emphasis on general principles with examples drawn from various animal phyla. Same as BIOL 430.

Prerequisite(s): BIOL 107 or BIOL 115 or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

BME 452**Control Systems for Biomedical Engineers**

Control systems design and analysis in biomedical engineering. Time and frequency domain analysis, impulse vs. step response, open vs. closed loop response, stability, adaptive control, system modeling. Emphasis is on understanding physiological control systems and the engineering of external control of biological systems.

Prerequisite(s): BME 330

Lecture: 3 Lab: 0 Credits: 3

BME 453**Quantitative Physiology**

This course provides a quantitative approach to fundamental physiological principles and systems. The course covers basic cell physiology, membrane transport, action potentials and excitable tissue, and skeletomuscular, nervous, cardiovascular, respiratory, renal, and endocrine systems.

Corequisite(s): BME 405

Prerequisite(s): BIOL 115

Lecture: 3 Lab: 0 Credits: 3

BME 455**Cardiovascular Fluid Mechanics**

Anatomy of the cardiovascular system. Scaling principles. Lumped parameter, one-dimensional linear and nonlinear wave propagation, and three-dimensional modeling techniques applied to simulate blood flow in the cardiovascular system. Steady and pulsatile flow in rigid and elastic tubes. Form and function of blood, blood vessels, and the heart from an engineering perspective. Sensing, feedback, and control of the circulation. Possible project using custom software to run blood flow simulations. Same as MMAE 455.

Prerequisite(s): BME 301 or MMAE 310 or MMAE 313 or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

BME 475**Neuromechanics of Human Movement**

Concepts from mechanics and neurophysiology will be introduced and employed to analyze and model human movement, especially of the extremities. Topics will include forward and inverse kinematics and dynamics, muscle modeling, and feedback control.

Prerequisite(s): BME 330 or ECE 308 or MMAE 305 or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

BME 482**Mass Transport for Biomedical Engineers**

This course seeks to provide students with an introduction to advanced concepts of mass transport with an emphasis on biological systems. Students will be exposed to derivation of the conservation equations for heat, mass, and momentum. Following derivation of these laws, focus will be placed on mass transport applications, including diffusion, convection-diffusion, diffusion with reactions, and facilitated diffusion. Students will be able to apply mass transport equations to solve problems in biological systems.

Prerequisite(s): BME 301 and CHE 202

Lecture: 3 Lab: 0 Credits: 3

BME 490**Senior Seminar**

Professional issues in bioengineering. Role of bioengineers in industry. Professional identity. Structure of bioengineering industries and product development process. Job market analysis. Current employment opportunities. Recruiting process and interview. Analysis of employer. Marketing versus engineering. Management by objective. Role of higher degrees.

Lecture: 1 Lab: 0 Credits: 1

Satisfies: Communications (C)

BME 491**Independent Study**

Focused reading and study under the supervision of a BME faculty member. A final written report is required to receive credit.

****Instructor permission required.****

Credit: Variable

Satisfies: Communications (C)

BME 492**Undergraduate Research**

Independent research (experimental or theoretical/computational) under the supervision of a BME faculty member. A final written report is required to receive credit. ****Instructor permission required.****

Credit: Variable

Satisfies: Communications (C)

BME 493**BME Undergraduate Project**

Research or design project involving 2 or more students under supervision of a BME faculty member. A final written report from each student is required to receive credit. ****Instructor permission required.****

Lecture: 3 Lab: 0 Credits: 3

BME 497**Special Problems**

Design, development, analysis or research on special topics defined by a faculty member or the department. ****Instructor permission required.****

Lecture: 0 Lab: 3 Credits: 3