BIOMEDICAL ENGINEERING (BME)

BME 1000 - Introduction to Biomedical Engineering I
Credit(s): 1 Credit
Introduction to the broad field of biomedical engineering. 1.000 Credit hours.

BME 1010 - Introduction to Biomedical Engineering II
Credit(s): 1 Credit
Continuation of BME 1000. Introduction to careers in the broad field of biomedical engineering. 1.000 Credit hours.

BME 2000 - BME Computing
Credit(s): 3 Credits
Introduction to computer modeling and analysis in biomedical engineering. Introduction to the MATLAB programming environment, develop algorithms and computer programs that address biomedical engineering problems.

Prerequisite(s): (Math Waiver per Advisor with a minimum score of 1520, MATH 1520 with a grade of C- or higher, or MATH 2530 with a grade of C- or higher)

BME 2200 - Applied Physiology for Engineers
Credit(s): 3 Credits
This course introduces students to the systems of the human body covering structure, function and regulation at multiple levels (cell, tissue, organ, system and body). By taking this course, students will: 1. Be able to describe the key components, structures and functions of the various human physiological systems. 2. Develop a qualitative understanding of how the various systems work together to achieve global (body) functions. 3. Enhance their ability to think critically and form solutions to conceptual problems. 4. Improve their technical communication skills (written and oral).

Prerequisite(s): BIOL 1240 with a grade of C- or higher

BME 2910 - Co-Op with Industry
Credit(s): 0 Credits (Repeatable for credit)
A full-time supervised work experience with an agency, firm or organization that employs persons in this degree field. This course is used for the first experiential learning session.

Restrictions:
Students with a classification of Freshman may not enroll.

BME 2930 - Special Topics
Credit(s): 3 Credits (Repeatable for credit)

BME 2980 - Independent Study
Credit(s): 1 or 3 Credits (Repeatable for credit)

BME 3000 - Engineering Entrepreneurship
Credit(s): 3 Credits
This course introduces students to the methods used to develop an innovative, technology-based product or service in a competitive environment. Topics covered include the start-up mindset, disruptive innovation, lean development techniques, patents and other intellectual property, medical regulatory affairs, finance, venture capital, and company valuation and harvest. Offered in fall.

Prerequisite(s): BME 3200 with a grade of C- or higher; ECE 2001 with a grade of C- or higher; ECE 2002 with a grade of C- or higher

BME 3100 - Signals
Credit(s): 3 Credits
Signal representations in the time domain and frequency domain, Fourier transforms, Laplace transforms, Z-transforms, linear systems, transfer functions, system response in time and frequency, analog and digital processing of signals. Relating signal properties to physical parameters. 3.000 Credit hours.

Prerequisite(s): BME 2000 with a grade of C- or higher; ECE 2001 with a grade of C- or higher; ECE 2002 with a grade of C- or higher; MATH 3550 with a grade of C- or higher

BME 3150 - Biomedical Instrumentation
Credit(s): 3 Credits
This course covers both clinical and medical research instrumentation. Specific examples include the design and application of electrodes, biopotential amplifiers, biosensors, therapeutic devices, clinical measurements, implantable devices, non-invasive methods, and medical imaging machines.

Prerequisite(s): (BME 3100 with a grade of C- or higher or ECE 3150 with a grade of C- or higher); (BME 2200 with a grade of C- or higher, BIOL 2600 with a grade of C- or higher, or BME 4930 with a grade of C- or higher)

BME 3200 - Mechanics
Credit(s): 3 Credits
Topics include analyses of systems at static equilibrium; analyses of the deformation and stress of elastic and plastic materials under various loading modes; and an introduction to viscoelasticity.

Prerequisite(s): PHYS 1610 with a grade of C- or higher

BME 3300 - Transport Fundamentals
Credit(s): 3 Credits
Introductory topics in fluid, heat, and mass transfer including both integral and differential analysis. Develop and utilize Bernoulli’s equation, Navier-Stokes relationships, Fourier heat transfer relationships, and Fick's laws. Analysis of problem statements and determination of assumptions for each set of equations is covered.

Prerequisite(s): (BME 2000 with a grade of C- or higher or CSCI 1060 with a grade of C- or higher); BME 3200 with a grade of C- or higher; MATH 3550 with a grade of C- or higher; (PHYS 3410 with a grade of C- or higher or ESCI 2300 with a grade of C- or higher)

BME 3400 - Materials Science
Credit(s): 3 Credits
Materials Science is a multidisciplinary field requiring knowledge of chemistry, physics, and mechanics. In this first course we examine the effect of chemistry on molecular structure and physical and mechanical properties of materials, and we examine methods of controlling those properties. Examples from the various engineering disciplines are used.

Prerequisite(s): BME 2000 with a grade of C- or higher; CHEM 1120 with a grade of C- or higher

BME 3840 - Junior Lab
Credit(s): 1 Credit (Repeatable for credit)
Laboratory to provide an experience in engineering design and experimentation. Students develop fundamental lab and analysis skills across a broad array of core BME topics, including mechanics, materials, transport, signals, and instrumentation. 1.000 Credit hours.

Prerequisite(s): BME 3400 with a grade of C- or higher; BME 3100 with a grade of C- or higher; BME 3300 with a grade of C- or higher

* Concurrent enrollment allowed.
BME 3850 - Design of BME Lab Experiments  
Credit(s): 1 or 2 Credits  
Laboratory to provide an experience in engineering research and design at a level appropriate to the student’s background. Students will work on developing their laboratory skills and ability to successfully design and implement a research plan.  
Restrictions:  
Enrollment is limited to students with a major in Biomedical Engineering.

BME 3930 - Special Topics  
Credit(s): 1-4 Credits (Repeatable for credit)

BME 3980 - Independent Study  
Credit(s): 1 or 3 Credits (Repeatable for credit)

BME 4100 - Biomedical Signals  
Credit(s): 3 Credits  
Physiological origins of measured signals. Digital processing of 1-dimensional (1D) and 2-dimensional (2D) biosignals. Digital processing of biomages. Computational tools in 1D & 2D. Relating signal properties to physiological parameters.  
Prerequisite(s): (BME 3100 with a grade of C- or higher or ECE 3150 with a grade of C- or higher); BME 2000 with a grade of C- or higher; (BME 2200 with a grade of C- or higher or BIOL 2600 with a grade of C- or higher)

BME 4130 - Medical Imaging  
Credit(s): 3 Credits  
This course introduces students to the physics, signals-and-systems, image processing, and clinical components of four widely used medical imaging technologies: X-ray (and angiography), computed tomography, magnetic resonance, and ultrasound. Coursework includes image processing in MATLAB and other medical image visualization platforms.  
Prerequisite(s): BME 3100 with a grade of C- or higher

BME 4150 - Brain Computer Interface  
Credit(s): 3 Credits  
This course introduces fundamental and advanced technologies in constructing prosthetic devices controlled by brain signals noninvasively. The topics will include the major BCI components, Electroencephalography (EEG) signal properties, acquisition and processing, the common research platform BCI2000, eye-movement tracking glasses, basic machine learning, classical and award-winning BCI research projects, etc. Students will gain a broad knowledge of the BCI research and its applications. The will learn the basics of brain-signal acquisition and processing. They will learn the four modules included in a typical BCI system. They will be able to work with a single-channel EEG system to measure brain signals and build complete applications on top of it.  
Prerequisite(s): BME 2000; BME 3100

BME 4200 - Biomechanics  
Credit(s): 3 Credits  
Advanced topics in skeletal tissue mechanics, including: skeletal biology, fracture healing, and bone remodeling; the mechanical properties, fracture resistance, and adaptability of bone to external forces; and the mechanics of synovial joints, cartilage, tendons, and ligaments.  
Prerequisite(s): (BME 2200 with a grade of C- or higher, BIOL 2600 with a grade of C- or higher, or BME 4930 with a grade of C- or higher); BME 3200 with a grade of C- or higher; BME 3400 with a grade of C- or higher

BME 4210 - Human Movement Biomechanics  
Credit(s): 3 Credits  
Theory behind and techniques of quantifying human movement, including segment and joint kinematics and kinetics, muscle activation, and simulation of musculoskeletal systems. (Offered every Spring)  
Prerequisite(s): BME 3200 with a grade of C- or higher

BME 4300 - Biotransport  
Credit(s): 3 Credits  
With the foundations of fluid, heat and mass transfer established in Transport Fundamentals, this course focuses on specific biological examples of transport including oxygen transport, blood flow and solute transport in biological systems. Additionally, discussion will include integration of fluid, heat and mass transfer in specific biomedical examples such as artificial organ development and extracorporeal devices. Prerequisite(s): C- or better in BIOL-2600 or BME-2200 and BME-3300.  
Prerequisite(s): (BIOL 2600 with a grade of C- or higher or BME 2200 with a grade of C- or higher); BME 3300 with a grade of C- or higher

BME 4310 - Advanced topics in Biotransport  
Credit(s): 3 Credits  
This course will explore advanced topics in transport phenomena, including utilizing dimensional analysis & unsteady state equations and studying multiple forms of transport simultaneously. Mathematical techniques to reduce and solve partial differential equations will be investigated to model biomedical systems more accurately. Prerequisites: BME430, BME440, BME310, & consent of instructor.  
Prerequisite(s): BME 3100; BME 4300; BME 4400; MENG 201

BME 4320 - Drug Delivery  
Credit(s): 3 Credits  
This course will cover various modes and engineered vehicles for drug delivery, including nano- and micro-spheres, transdermal drug delivery systems (DDS), implant drug delivery, targeted delivery, and hydrogels for controlled delivery. The class will also cover mass transport fundamentals: especially diffusion, but also convection and basic pharmacokinetics models. Offered periodically.  
Prerequisite(s): BME 3300 with a grade of C- or higher; BME 4400 with a grade of C- or higher

BME 4400 - Biomaterials  
Credit(s): 3 Credits  
Biomaterials is a multidisciplinary field requiring knowledge of biology, chemistry, materials science, mechanics, transport and medicine. In this course we will examine aspects of chemistry, biology, material science and mechanics as they apply to the interaction of a material with a biological system. Our examination of the field will lead to a general understanding of biocompatibility and how to design experiments that assess biocompatibility.  
Prerequisite(s): BME 3400 with a grade of C- or higher; (BIOL 2600 with a grade of C- or higher or BME 2200 with a grade of C- or higher); (PHYS 3410 with a grade of C- or higher or ESCI 2300 with a grade of C- or higher); (STAT 3850 with a grade of C- or higher or MATH 3850 with a grade of C- or higher)  
* Concurrent enrollment allowed.
BME 4410 - Tissue Engineering
Credit(s): 3 Credits
This course will explore quantitative topics in tissue engineering, including utilizing engineering topics such as materials science, kinetics and transport phenomena to describe biological processes in tissue engineering. 0.00 Credit hours.
Prerequisite(s): BME 3300 with a grade of C- or higher; BME 4400 with a grade of C- or higher; (STAT 3850 with a grade of C- or higher or MATH 3850 with a grade of C- or higher)

BME 4430 - Regenerative Engineering
Credit(s): 3 Credits
Fundamental concepts of cell biology, stem cell therapy, immune-modulation, mechanical and electrical stimulation will be introduced. Relevant peer-reviewed journal articles will be discussed. (Offered every Spring)
Prerequisite(s): BME 4410 with a grade of C- or higher

BME 4500 - Numerical Methods in BME
Credit(s): 3 Credits
This course will explore numerical methods to characterize a variety of the major topics in Biomedical Engineering (transport phenomena, measurements, materials, mechanics and signals). Topics range from simple modeling of biosystems to steady and dynamic behavior of these systems. Various modeling tools and applications will also be explored. The course will utilize Matlab as its primary programming tool.
Prerequisite(s): BME 2000 with a grade of C- or higher
Restrictions:
Enrollment limited to students with a classification of Senior.

BME 4600 - Quantitative Physiology I
Credit(s): 3 Credits
In this course, students will quantitatively examine aspects of human physiology related to neural control and the sensory systems. The topics will cover excitable cells, the nervous system, chemical senses, hearing, vision, and the neuromuscular system. This examination of the field will lead to a quantitative understanding of how these systems work alone and integrate with one another.
Prerequisite(s): BME 2000 with a grade of C- or higher; BME 3100 with a grade of C- or higher; BME 3300 with a grade of C- or higher
Restrictions:
Enrollment is limited to students with a program in Biomedical Engineering.

BME 4650 - Quantitative Physiology II
Credit(s): 3 Credits
In this course, students will quantitatively examine aspects of human physiology related to a number of body systems. The topics will cover cardiovascular physiology, respiratory physiology, renal physiology, gastrointestinal physiology, and endocrine. This examination of the field will lead to a quantitative understanding of how these systems work alone and integrate with one another.
Prerequisite(s): BME 4600 with a grade of C- or higher

BME 4660 - Special Topics in Biomedical Engineering
Credit(s): 3 Credits (Repeatable for credit)
Experimental or one-time courses of special interest. Course must be approved by BME faculty prior to offering.
Prerequisite(s): BIOL 1240 with a grade of C- or higher

BME 4950 - Senior Project I
Credit(s): 3 Credits
Capstone project; process of design; proposal development; project planning and scheduling; prototyping; quality; testing; regulatory issues; biomedical ethics; design review; teamwork; oral and written reports.
Prerequisite(s): BME 3150 with a grade of C- or higher; BME 3840 with a grade of C- or higher

BME 4960 - Senior Project II
Credit(s): 3 Credits
Continuation of BME 4950.
Prerequisite(s): BME 4950 with a grade of C or higher

BME 4970 - Independent Research
Credit(s): 0-2 Credits (Repeatable for credit)
Individual or small group investigation of a topic. Pass/Fail grading only.

BME 4980 - Independent Research
Credit(s): 1-3 Credits (Repeatable for credit)
Individual or small group investigation of a topic. Prerequisites: Consent of instructor.

BME 5010 - Research Analysis
Credit(s): 2 Credits
Introduction to scientific design, critique, communication, and analysis for biomedical engineers. Offered every fall semester.

BME 5030 - Accelerated Introduction to Neuroengineering and Bioimaging
Credit(s): 2 Credits
Introduction to the principles of neuroscience and basic engineering approaches to study the human brain at cellular and systems levels. The course will also cover how brain anatomy, function and disease are evaluated using medical imaging techniques. Offered every fall semester.

BME 5040 - Technical Communication in the Discipline
Credit(s): 1 Credit
This class will focus on written technical communication in Biomedical Engineering – an essential skill for every graduate student. The students will learn how to write the various sections of a research paper, namely: Abstract, Introduction, Materials and Methods, Results, Discussion, Conclusions. They will also learn how to present and interpret scientific data, how to format figures and figure captions, how to properly cite, including how to use EndNote, how to choose the proper journal for their work, and how to approach paper revisions. The students will also learn strategies to overcome writers block. While different written assignments will be graded throughout the semester, the final deliverable from this class will be a complete written research paper. Thus, the class is tailored towards Master’s students in their last semester or PhD students typically in their second year or beyond, who are preparing their first manuscript. However, students who have a well-defined project and significant preliminary data could also benefit from the instruction. Offered in spring.
BME 5050 - Data Handling  
Credit(s): 3 Credits  
This required course addresses issues of data acquisition, filtering, model fitting, analysis, and visualization. The data will include one-dimensional signals, images, and multidimensional data. The course will serve as a general overview of data handling, and some students may follow with more specialized courses that address the specific topics. Offered every spring semester.

BME 5060 - Ethics & Compromise  
Credit(s): 3 Credits  
Students and faculty will discuss the positive and negative impact of engineering and science on society. Examples and case studies will illustrate the scientific, economic, and social effects of new devices and new knowledge. The discussion will focus on the role of engineers and scientists, the ethical considerations, and the acceptable compromises. Offered every year.

BME 5130 - Medical Imaging  
Credit(s): 3 Credits  
This course introduces students to the physics, signals-and-systems, image processing, and clinical components of four widely used medical imaging technologies: X-ray (and angiography), computed tomography, magnetic resonance, and ultrasound. Coursework includes image processing in MATLAB and other medical image visualization platforms. Students enrolled in the graduate section (BME5130) and receiving graduate credit for this course will be expected to work at the higher level. For example, there will be additional assignments, reading, research topics, and/or presentations assigned by the instructor.

Prerequisite(s): BME 3100

BME 5150 - Brain Computer Interface  
Credit(s): 3 Credits  
This course introduces fundamental and advanced technologies in constructing prosthetic devices controlled by brain signals noninvasively. The topics will include the major BCI components, Electroencephalography (EEG) signal properties, acquisition and processing, the common research platform BCI2000, eye-movement tracking glasses, basic machine learning, classical and award-winning BCI research projects, etc. Students will gain a broad knowledge of the BCI research and its applications. They will learn the basics of brain-signal acquisition and processing. They will learn the four modules included in a typical BCI system. They will be able to work with a single-channel EEG system to measure brain signals and build complete applications on top of it. Graduate students will lead the design groups and will apply more advanced analysis techniques than the undergraduates.

BME 5200 - Continuum Biomechanics  
Credit(s): 3 Credits  
This course will cover various modes and engineered vehicles for drug delivery, including nano- and micro-spheres, transdermal drug delivery systems (DDS), implant drug delivery, targeted delivery, and hydrogels for controlled delivery. The class will also cover mass transport fundamentals: especially diffusion, but also convection and basic pharmacokinetics models.

BME 5400 - Tissue-Material Interfaces  
Credit(s): 3 Credits  
This course will expand on the concepts introduced in the typical undergraduate biomaterials sequence. In particular, the response of tissues to implanted materials will be studied extensively. Offered every spring semester.

BME 5410 - Tissue Engineering  
Credit(s): 3 Credits  
Beginning with the history of tissue engineering, this course will describe the challenges in developing new functional human tissue including the ethical and legal implications of 'designing' tissue, relevant background, and current directions in research and development. Offered every other fall semester.

BME 5420 - Tissue Engineering Scaffold Fabrication Techniques  
Credit(s): 3 Credits  
This course will explore various techniques for fabricating and assessing scaffolds for tissue engineering applications. This course will provide students with classroom instruction and hands-on laboratory experience with a number of scaffold fabrication techniques; such as electrospraying, various hydrogels technologies, cryogels, tissue decellularization, solvent casting, and particular leaching. Students will also learn about and perform a number of assessments for these scaffolds, and may learn about swelling and degradation testing, mechanical testing, scanning electron and atomic force microscopy imaging, and cell seeding and interaction studies. Prerequisite: BME 5410 Tissue Engineering Offered periodically as needed.

Prerequisite(s): BME 5410

BME 5430 - Regenerative Engineering  
Credit(s): 3 Credits  
Fundamental concepts of cell biology, stem cell therapy, immune-modulation, mechanical and electrical stimulation will be introduced. Relevant peer-reviewed journal articles will be discussed. Students enrolled in the graduate section (BME 5430) and receiving graduate credit for this course will be expected to work at the higher level. For example, there will be additional assignments, reading, research topics, and/or presentations assigned by the instructor.

Prerequisite(s): BME 4410 or BME 5410

BME 5450 - AFM Techniques and Training  
Credit(s): 1-2 Credits (Repeatable for credit)  
Laboratory to provide an experience and training in atomic force microscopy (AFM) to allow graduate students the ability to utilize the equipment in their research. Students will be exposed to AFM background, along with directed training and independent use of the microscope. Course requires instructor's approval.

BME 5500 - Experimental Technique and Design  
Credit(s): 1-2 Credits  
Laboratory to provide an experience in engineering research and design at a level appropriate to the student's background. Students will work on developing their laboratory skills and ability to successfully design and implement a research plan. Course open to BME graduate students with Instructor's permission.
BME 5600 - Quantitative Physiology I  
Credit(s): 3 Credits  
In this course, students will quantitatively examine aspects of human physiology related to neural control and the sensory systems. The topics will cover excitable cells, the nervous system, chemical senses, hearing, vision, and the neuromuscular system. This examination of the field will lead to a quantitative understanding of how these systems work alone and integrate with one another. Offered as needed in fall.

BME 5650 - Quantitative Physiology II  
Credit(s): 3 Credits  
In this course, students will quantitatively examine aspects of human physiology related to a number of body systems. The topics will cover cardiovascular physiology, respiratory physiology, renal physiology, gastrointestinal physiology, and endocrine. This examination of the field will lead to a quantitative understanding of how these systems work alone and integrate with one another. Offered as needed in spring.  
Prerequisite(s): BME 5600

BME 5800 - Research Rotation  
Credit(s): 1-3 Credits  
Students with or without previous research experience are provided the opportunity to carry out a research project with the guidance of a faculty member. A wide variety of topic in the fields of tissue engineering, biomaterials, biomechanics, biosignals, and biomeasurements are available. Course open to BME Graduate Students.

BME 5930 - Special Topics  
Credit(s): 1-3 Credits (Repeatable for credit)  
A one-time or trial course.

BME 5955 - Capstone Project 1  
Credit(s): 3 Credits  
A capstone project for the BS degree combined with the beginning of research toward the MS degree; process of design; proposal development; project planning and scheduling; prototyping; quality; testing; regulatory issues; biomedical ethics; design review; teamwork; oral and written reports. Restricted to students in the Accelerated BS-MS Program in Engineering.

BME 5960 - Project Guidance  
Credit(s): 0-3 Credits (Repeatable for credit)  
For the M.S. project option.

BME 5965 - Capstone Project 2  
Credit(s): 3 Credits  
Continuation of BME 5955. Restricted to students in the Accelerated BS-MS Program in Engineering.  
Prerequisite(s): BME 5955

BME 5970 - Research Topics  
Credit(s): 1-3 Credits (Repeatable for credit)  
For research other than the thesis or project.

BME 5980 - Graduate Reading Course  
Credit(s): 1-3 Credits (Repeatable for credit)  
An independent study with a faculty member.

BME 5990 - Dissertation Research  
Credit(s): 0-6 Credits (Repeatable for credit)

BME 6930 - Special Topics  
Credit(s): 1-6 Credits (Repeatable for credit)  
A one-time or trial course.

BME 6970 - Research Topics  
Credit(s): 1-3 Credits  
For research other than dissertation research.