Approved Track Courses

Requirements for each of the 4 specializations:

- A total of 5 courses from the select list for that specialization.
- ***At least 3 of the 5 courses must be engineering courses.***

Neural Engineering

Neural engineers apply engineering principles and methods to study the nervous system and to develop technology to treat nervous disorders. Neural engineering has two broadly defined goals. First, it aims to understand normal brain functions at the level of single cells, networks of cells, brain systems, and complex behavior. Second, it aims to develop diagnostic and therapeutic technologies to help restore brain functions impaired by neurological/psychiatric diseases and injuries.

Engineering courses (at least 3 required):

ABE 4033 Fundamentals and Applications of Biosensors
Credits: 3; Prerequisite: MAP 2302, BSC 2010 and CHM 2200.
Provides a broad introduction to the field of biosensors, as well as an in-depth and quantitative view of biosensor design and performance analysis. Fundamental application of biosensor theory will be demonstrated, including: recognition, transduction, signal acquisition, and post processing/data analysis.

ABE 5038 Recent Developments and Applications in Biosensors
Credits: 3; Prerequisite: At least senior status in engineering and background in biology including biomolecules.
Introduction to biosensors, design and performance analysis. Fundamental application of biosensor theory will be demonstrated, including recognition, transduction, signal acquisition, and post processing/data analysis.

BME 3508 Biosignals and Systems
Credits: 3; Prerequisite: MAC 2313 with minimum grade of C.
Basic theory and techniques of biosignals and systems. Topics include sampling, noise in biological signals, signal averaging of noisy biological signals, Fourier analysis and filtering.

BME 4931 Biomedical Engineering for Global Heath*
Credits: 3.
This course will broaden understanding of global health concerns and how healthcare technologies can play a role in improving human health in developed and developing regions. The course will cover global health demographics and comparative health systems, plus selected major health problem areas. Basic quantitative and design principles of biomedical engineering as well as introductory epidemiology principles will be covered, and examples will highlight of the impact of biomedical technology on global health. Legal, ethical and cultural issues associated with developing and disseminating new medical technologies will be considered. Topics will be taught at the sophomore level, and to be accessible to non-engineering students and beginning engineering students.
*Special topics course – not offered every term.

Approved Track Courses

BME 4931 Biomedical Informatics*
Credits: 3; Prerequisite: Basic knowledge of programming, statistics, and probability.
This is an undergraduate level course designed for students interested in health and biomedical informatics problems. It explores major concepts of health and biomedical informatics such as clinical decision support systems, natural language and text processing in health care and biomedicine, and biomedical information retrieval.
**Special topics course – not offered every term.*

BME 4931 Imaging System Analysis*
Credits: 3; Prerequisite: MAC2311, MAC2312, and MAC2313 or equivalent.
The application of linear systems theory for the analysis of medical imaging systems with an emphasis on radiological imaging. Topics covered include the following: convolution, Fourier Transform, linear filtering, sampling theory, image reconstruction from projections and methods for image quality evaluation.
**Special topics course – not offered every term.*

BME 4931 Neural Engineering*
Credits: 3; Prerequisite: BME 3508 or equivalent Signals and Systems course.
Applying engineering to neuroscience including such diverse areas as neural tissue engineering, models of neural function, and neural interface technology. Focuses mainly in the context of neural interfaces and prosthetics, from basic neural physiology and models of neural mechanisms to advanced neural interfaces currently in development or produced commercially.
**Special topics course – not offered every term.*

BME 4931 Neural Systems Modeling*
Credits: 3; Prerequisite: BME 3508 or consent of the instructor, basic level programming in Matlab, introduction to Laplace and Fourier analyses, and introduction to AC circuit sinusoidal analysis.
The first half of the course covers the use of selected classical modeling techniques as applied to understanding of neuro-electric activity. The second half of the course covers introduction to and selected applications of functional MRI for understanding brain function.
**Special topics course – not offered every term.*

BME 5704 Advanced Computational Methods for Biomedical Engineers
Credits: 3; Prerequisite: Only a basic knowledge of physics and calculus is required.
This course covers advanced mathematics from a biomedical engineering perspective. Linear and nonlinear systems, partial differential equations, optimization and inverse problems will be discussed. Advanced mathematical techniques are increasingly needed in today's biomedical engineering. For example, one needs a nonlinear system to describe a model or problem in neural engineering. Finite element has been a powerful numerical method to deal with many problems in biomechanics and biomaterials where partial differential equations are involved. Inverse problems are common almost everywhere in the field of biomedical imaging. This course is geared towards the applications of the advanced mathematical techniques to various biomedical engineering problems.

BME 6938 Data Math
Credits: 3.
Advanced data science technology with Matlab to analyze biomedical data.

Approved Track Courses

BME 6938: Neural Instrumentation
Credits: 3.
This course covers engineering and medical bases of application, measurement and processing of signals to and from the nervous system of living systems. Biomedical transducers for measurements of movement, biopotentials, pressure, flow, concentrations, and temperature are discussed, as well as treatment devices.

DEP 4930 The Developing Mind and Brain: Developmental Cognitive Neuroscience
Credits: 3.
Ever wonder how the brain develops? Or how the developing brain supports learning, memory, attention or emotion processing? Are there important time periods or sensitive periods for brain development? And what happens when things go wrong? This course will be a broad overview of current research and methods in the field of developmental cognitive neuroscience. We will start with a basic overview of how the brain develops from conception into adulthood. We will then discuss different theories related to how the brain develops and the role of experience in this development. We will then learn about the methods researchers use to study the developing brain in humans including MRI/fMRI, electrophysiological techniques (including EEG and ERPs), and optical imaging. A part of this course will be devoted to learning to design studies, which use the above methods to study development (a final paper will be related to this). This course will examine what we know about the neural mechanisms involved in the development of memory, language, object and face perception, attention, emotion, social processing, and learning. We will also discuss research using neuroscience methods to investigate atypically (e.g., Autism, ADHD, Dyslexia, PKU, etc.) developing populations.

EEE 4260C Bioelectrical Systems
Credits: 4; Prerequisite: EEL 3008 and EEL3112.
Covers the theoretical and quantitative perspective of bioelectrical signals reflecting the activity of the brain, the muscles, and the heart. Examines bases of modeling, measuring, processing and analyzing bioelectrical signals and systems, as well as common clinical applications. *Laboratory.*

EEL 3008 Physics of Electrical Engineering
Credits: 3; Prerequisites: EEL 3111C, MAC 2313, and MAP 2302.
Introduces the fundamental physics underlying components and devices and their application to electronics, power, and wireless.

EEL 3112 Circuits 2
Credits: 3; Prereq: EEL 3000, EEL 3111C, EEL 3135 and MAP 2302.
Continuous-time signals and linear systems: Fourier series and transforms, frequency, response, Laplace transform and system function, analog filters; emphasis on electrical circuits. Sampling.

EEL 3135 Introduction to Signals and Systems
Credits: 4; Prerequisite: MAC 2312.
Continuous-time and discrete-time signal analysis including Fourier series and discrete-time and discrete Fourier transforms; sampling; discrete-time linear system analysis with emphasis on FIR and IIR systems: impulse response, frequency response, and system function; MATLAB based programming for Signals and Systems.

Approved Track Courses

EEL 4750 Foundations of Digital Signal Processing
Credits: 3; Prerequisite: EEL 3135.
Analysis and design of digital filters for discrete signal processing, spectral analysis and fast Fourier transform.

EEL 4930 Introduction to Biophotonics
Credits: 3; Prerequisites: PHY2049.
Introduction to the principles of optics, lasers and biology, the interaction of light with cells and tissues, and various optical imaging, sensing and activation techniques and their applications in biomedicine.

EEL 5934 Neural Signals, Systems, and Technology
Credits: 3; Prerequisite: While there are no formal prerequisites, it is expected that students interested in this topic will have a graduate standing in engineering and/or neuroscience (or undergraduate senior standing with approval from the instructor). Even if class material may span topics in one discipline unfamiliar to students in the other discipline, it is expected that students will acquire the necessary knowledge during the semester, either by reading supplementary material or through interaction with the instructor.
Biophysical principles of neural signaling, characterization of neural circuits and systems, technology design principles for interfacing with biological neural systems, overview of clinical applications and industrial opportunities for neurotechnology.

EEL 6537 Spectral Estimation
Credits: 3; Prerequisite: EEL 5544, EEE 5502.
Measurement and analysis of signals and noise. Digital filtering and spectral analysis; fast Fourier transform.

EEL 6825 Pattern Recognition and Intelligent Systems
Credits: 3.
Decision functions; optimum decision criteria; training algorithms; unsupervised learning; feature extraction, data reduction; potential functions; syntactic pattern description; recognition grammars; machine intelligence.

EEL 6935 Biometric Identification
Credits: 3; Prerequisite: Basic Mathematics – Knowledge and ability to use calculus, probability, and statistics are essential.
Methods and principles for the automatic identification/authentication of individuals. Technologies include fingerprint, face, and iris biometrics. Additional topics include biometric system design, performance evaluation, multi-modal biometric systems, and biometric system security.

EEL 6935 Deep Learning
Credits: 3.
Nonlinear modeling in neural networks and kernel spaces. Gradient descent learning in the additive neural model. Statistical Learning Concepts. Information theoretic cost functions. Convolution neural networks. Recurrent neural networks. Foundations of Deep Learning. Importance of Deep learning for representation. Current models for image and speech recognition. Challenges of Deep Learning.

EGM 3344 Introduction to Numerical Methods of Engineering Analysis
Credits: 3; Prerequisite: MAC 2313 and COP 2271; Corequisite: MAP2302.

Methods for numerical solution of mathematical problems with emphasis on engineering applications using MATLAB. Includes roots, optimization, linear algebraic equations, matrices, curve fitting, differentiation, integration and ordinary differential equations.

EGM 4313 Intermediate Engineering Analysis
Credits: 3; Prerequisite: MAP 2302 and EGM 3344.
Ordinary differential equations, systems of ordinary differential equations, partial differential equations, Fourier series and complex analysis. Also includes equations of heat conduction, wave propagation and Laplace.

EGN 4912 Engineering Undergraduate Research
Credits: 0-3.
The primary purpose of this course is to provide the student an opportunity for firsthand, supervised research. “Research” is defined as mentored, but self-directed, work that enables individual students or a small group of students to explore an issue of interest to them and to communicate the results to others. Projects may involve inquiry, design, investigation, scholarship, discovery, or application, depending on the topic, and the student is aware of how her or his project fits into and contributes to solving the larger problem to which it belongs. The student will usually assist a faculty member with a research project by helping to prepare the study and contributing in a meaningful way in meeting the objectives of the study. The student may work with a graduate student who is performing research supervised by a research faculty member.

EMA 3066 Introduction to Organic Materials
Credits: 3; Prerequisite: EMA 3010 and one of the following: EMA 3011, CHM 2200 or CHM 2210.
Uses, structure, processing and properties of organic materials, including polymers, biomacromolecules and small molecule organic materials. Scientific principles are introduced through discussion of developed organic materials for high technology applications.

EMA 4061 Biomaterials: Structure & Properties
Credits: 3; Corequisite: EMA 3066.
Materials commonly used for biomedical application, such as their properties from a biocompatibility or medical device perspective. In addition, materials interactions with biological systems are examined from the molecular (e.g., protein), cellular, tissue and systemic (whole body) perspective. This is the foundation for the second biomaterials class, which applies these principles toward the application of biomaterials in medical implants, prostheses and devices, along with the regulatory issues associated with biomaterials development.

ESI 4327C Matrix and Numerical Methods in Systems Engineering
Credits: 4; Prerequisite: MAC 2313 and MAP 2302 with minimum grades of C.
Theory and application of vector, matrix and other numerical methods to systems problems. Simultaneous linear equations, characteristic values, quadratic forms, error analysis, use of series, curve fitting, nonlinear equations, discrete methods. Laboratory emphasize numerical solutions using MATLAB.

Approved Track Courses

Math/Science courses (these do NOT fulfill the 3 engineering course requirement):

GMS 6780 Addiction: Neurotrends
Credits: 3; Prerequisite: *Bachelor's degree or higher from a regionally accredited institution or equivalent*
Presenting findings from leading-edge neuroscience research on how different drugs act on the brain, and how differences in age, gender and other factors influence those effects. It introduces different types of drugs, and describes global trends in substance use disorders and addiction.

PSB 3002 Physiological Psychology
Credits: 3; Prerequisite: PSY 2012.
Survey of the biological basis of behavior with special relevance to psychology. Students cannot take both PSB 3002 and PSB 3340. (B)

PSB 3340 Behavioral Neuroscience
Credits: 3; Prerequisite: BSC 2010.
Neuroanatomatical, chemical and electrophysiological studies in the biological basis of behavior. Students cannot take both PSB 3002 and PSB 3340 (PSB 3340 is recommended for IDS majors in neurobiological sciences). (B)

PSB 4434 Neurochemistry, Pharmacology and Behavior
Credits: 3; Prerequisite: PSB 3002 or PSB 3340, or instructor permission.
Advanced discussion of neurotransmitters, neuromodulators and the action of neuroactive drugs in relation to behavior. (B)

PSB 4654 Chemical Sense and Behavior
Credits: 3; Prerequisite: PSB 3002 or PSB 3340, or instructor permission.
Discussion of neural mechanisms and function of chemical senses, and the interaction with physiologic state and motivational aspects. (B)

PSB 4934 Neurobiology of Substance Abuse*
Credits: 3.
This course presents an overview of neurobiological models for understanding why some individuals transition from casual use to substance abuse. Approaches to treatment will be considered.
**Special topics course – not offered every term.*

Medical Physics and Imaging

Medical physicists are involved with patient care, research into new medical technologies, and teaching. There are four sub-specialties of medical physics: diagnostic medical physicists, nuclear medical physicists, therapeutic medical physicists, and medical health physicists. Prospective students are encouraged to visit the website of the American Association for Physicists in Medicine (AAPM) – www.aapm.org – for further information.

Biomedical imaging involves the basic science, engineering, and physics of image acquisition and data processing applied to the imaging of structure and function at the molecular, cellular, tissue, and organ levels of analysis. Prospective students are encouraged to visit the website of the IEEE Engineering in Medicine & Biology Society (EMB) – www.embs.org – for further information.

Engineering courses (at least 3 required):

BME 3508 Biosignals and Systems
Credits: 3; Prerequisite: MAC 2313 with minimum grade of C.
Basic theory and techniques of biosignals and systems. Topics include sampling, noise in biological signals, signal averaging of noisy biological signals, Fourier analysis and filtering.

BME 4931 Biomedical Engineering for Global Heath
Credits: 3.
This course will broaden understanding of global health concerns and how healthcare technologies can play a role in improving human health in developed and developing regions. The course will cover global health demographics and comparative health systems, plus selected major health problem areas. Basic quantitative and design principles of biomedical engineering as well as introductory epidemiology principles will be covered, and examples will highlight of the impact of biomedical technology on global health. Legal, ethical and cultural issues associated with developing and disseminating new medical technologies will be considered. Topics will be taught at the sophomore level, and to be accessible to non-engineering students and beginning engineering students.

BME 4931 Biomedical Informatics*
Credits: 3; Prerequisite: Basic knowledge of programming, statistics, and probability.
This is an undergraduate level course designed for students interested in health and biomedical informatics problems. It explores major concepts of health and biomedical informatics such as clinical decision support systems, natural language and text processing in health care and biomedicine, and biomedical information retrieval.
**Special topics course – not offered every term.*

BME 4931 Introduction to Medical Physics*
Credits: 3; Prerequisite: Undergraduate equivalent of BME 6590.
Introducing students to the physical basis and clinical practice of medical physics. Fundamentals of imaging physics and techniques including radiographic, CT, ultrasound, MRI and nuclear medicine procedures. Image quality metrics are introduced and the fundamental strategies of radiation therapy, treatment planning and components of professional development are studied.
**Special topics course – not offered every term.*

Approved Track Courses

BME 4931 Imaging System Analysis*
Credits: 3; Prerequisite: MAC2311, MAC2312, and MAC2313 or equivalent.
The application of linear systems theory for the analysis of medical imaging systems with an emphasis on radiological imaging. Topics covered include the following: convolution, Fourier Transform, linear filtering, sampling theory, image reconstruction from projections and methods for image quality evaluation.
**Special topics course – not offered every term.*

BME 6502 Introduction to Medical Imaging
Credits: 3.
Modern medical imaging technologies from a biomedical engineering perspective. The physics, mathematics, instrumentation and clinical applications of all common medical imaging modalities including x-ray radiography, computed tomography (CT), ultrasound imaging, positron emission tomography (PET), and magnetic resonance imaging (MRI) with a focus on non-ionizing radiation will be discussed. Emerging imaging modalities including diffuse optical tomography (DOT), Fluorescence Molecular Tomography (FMT), and photoacoustic tomography (PAT) will also be introduced.

BME 6533 Radiologic Anatomy
Credits: 3.
Imaging techniques as they relate to human anatomy and physiology.

BME 6535 Radiological Physics, Measurements and Dosimetry
Credits: 3; Prerequisite: *Upper level college physics*.
Interacting and measuring techniques for x-rays, gamma rays, neutrons and charged particles with matter; radioactive decay processes ion chamber measurements, scintillation detectors, and dosimetry techniques. Applications of cavity theory and dosimetry measurement in medical physics.

BME 6590 Medical Physics
Credits: 3; Prerequisite: BME 6534 Radiological Physics or permission of instructor.
Introducing students to the physical basis and clinical practice of medical physics. Fundamentals of imaging physics and techniques including radiographic, CT, ultrasound, MRI and nuclear medicine procedures. Image quality metrics are introduced and the fundamental strategies of radiation therapy, treatment planning and components of professional development are studied.

BME 6591 Therapy Radiation Physics 1
Credits: 3; Prerequisite: BME 6534 Radiological Physics or permission of instructor.
Introducing students to the principles of therapeutic radiological physics including the measurement and calculation of absorbed dose and dosimetric calculations. Studying external beam radiation therapy including dose distributions within patients and the treatment planning techniques used to produce desired isodose distributions.

EEL 3135 Introduction to Signals and Systems
Credits: 4; Prerequisite: MAC 2312.
Continuous-time and discrete-time signal analysis including Fourier series and discrete-time and discrete Fourier transforms; sampling; discrete-time linear system analysis with emphasis on

FIR and IIR systems: impulse response, frequency response, and system function; MATLAB based programming for Signals and Systems.

EEL 4750 Foundations of Digital Signal Processing
Credits: 3; Prerequisite: EEL 3135.
Analysis and design of digital filters for discrete signal processing, spectral analysis and fast Fourier transform.

EGM 3344 Introduction to Numerical Methods of Engineering Analysis
Credits: 3; Prerequisite: MAC 2313 and CGS 2421, or equivalent; Corequisite: MAP2302.
Methods for numerical solution of mathematical problems with emphasis on engineering applications using MATLAB. Includes roots, optimization, linear algebraic equations, matrices, curve fitting, differentiation, integration and ordinary differential equations.

EGN 4912 Engineering Undergraduate Research
Credits: 0-3.
The primary purpose of this course is to provide the student an opportunity for firsthand, supervised research. “Research” is defined as mentored, but self-directed, work that enables individual students or a small group of students to explore an issue of interest to them and to communicate the results to others. Projects may involve inquiry, design, investigation, scholarship, discovery, or application, depending on the topic, and the student is aware of how her or his project fits into and contributes to solving the larger problem to which it belongs. The student will usually assist a faculty member with a research project by helping to prepare the study and contributing in a meaningful way in meeting the objectives of the study. The student may work with a graduate student who is performing research supervised by a research faculty member.

ENU 4605 Radiation Interactions and Sources I
Credits: 4; Corequisite: ENU 4001.
Three one-hour lectures discussing interaction of ionizing radiation with matter; cross sections and radiation fields with emphasis on photons, heavy charged particles and electrons.

ENU 4630 Fundamental Aspects of Radiation Shielding
Credits: 3; Prerequisite: ENU 4605 with a minimum grade of C.
Three one-hour lectures discussing basic principles of radiation shielding. Study of radiation sources and shielding design for radiation facilities.

ENU 4641C Applied Radiation Protection
Credits: 2; Prerequisite: ENU 4605 with a minimum grade of C and ENU 4630.
Two one-hour lectures of introduction to practical radiation protection techniques and practices, including laboratory experiences. Examination of pertinent regulations, current practice, ethics and instrumentation/measurement practices. Design of facilities and controls to optimize benefits of radiation applications and minimize exposure risks. (WR)

Math/Science courses (these do NOT fulfill the 3 engineering course requirement):

PHY 3101 Introduction to Modern Physics
Credits: 3; Prerequisite: PHY 2049 or the equivalent.
Modern and atomic physics, relativity, wave phenomena and the basis of quantum physics. (P)

ENU 5626 Radiation Biology
Credits: 3; Prerequisite: One year each of college biology, chemistry, and physics; permission of instructor.
Effects of radiation on biological molecules, cells, and man including cancer and mutagenesis; use of radiation in treatment of disease.

ENU 6636 Medical Radiation Shielding & Protection
Credits: 3; Prerequisite: BME 6535 Radiological Physics, Measurements and Dosimetry.
Shielding design fundamentals. Methods of calculating gamma-ray attenuation, fast neutron penetration, effects of ducts and voids in shields, problems of heat generation and deposition in reactor components.

MAS 3114 Comp Linear Algebra
Credits: 3; Prerequisite: MAC 2312, MAC 2512 or MAC 3473 with a minimum grade of C and experience with a scientific programming language.
Linear equations, matrices and determinants. Vector spaces and linear transformations. Inner products and eigenvalues. Emphasizes computational aspects of linear algebra.

Biomaterials

Broadly classified, biomaterials are materials, whether synthetic or derived from nature, that interact with biological systems. The Biomaterials track will provide BME undergraduate students advanced coursework focusing on both fundamental aspects of material properties as well as state-of the art techniques for fabrication (including biomimetic synthesis), processing and application of materials in biomedical engineering.

To stay on schedule for this track, student must complete EMA3010 Materials before enrolling in the fall semester of their junior year. Otherwise, students will have difficulty completing the requirements by the spring semester of their junior year.

Engineering courses (5 required)

BME 4931 Biomedical Engineering for Global Heath
Credits: 3.
This course will broaden understanding of global health concerns and how healthcare technologies can play a role in improving human health in developed and developing regions. The course will cover global health demographics and comparative health systems, plus selected major health problem areas. Basic quantitative and design principles of biomedical engineering as well as introductory epidemiology principles will be covered, and examples will highlight of the impact of biomedical technology on global health. Legal, ethical and cultural issues associated with developing and disseminating new medical technologies will be considered. Topics will be taught at the sophomore level, and to be accessible to non-engineering students and beginning engineering students.
**Special topics course – not offered every term.*

BME 4931 Biodegradable Materials for Regenerative Medicine Applications*
Credits: 3.
This course introduces the students to biomaterials used in regenerative medicine and tissue engineering. This course will highlight chemical and physical properties of various natural and synthetic biomaterials, and how these features relate to choosing a material for a regenerative medicine application. This course will also provide tissue-specific examples of successful tissue regeneration.
**Special topics course – not offered every term.*

BME 4931 Mechanics of Biomaterials and Tissue*
Credits: 3.
This course covers how biomaterials and tissue respond to mechanical loads and stress. The course will first review the basic material compositions of metals, ceramics, and polymers. The course will then focus of the response of the mechanical response of these materials to loads and stress commonly experienced in the biological environment.
**Special topics course – not offered every term.*

Approved Track Courses

BME4931: Biomaterials for Drug Delivery*
Credits: 3.
This course focuses on the principles of engineering controlled release systems, and integrates topics in polymer chemistry, biomaterials, pharmacokinetics/pharmacodynamics, and mass transport phenomena.
**Special topics course – not offered every term.*

BME 4160 Magnetic Biomaterials
Credits: 3; Prerequisite: PHY 2048 and CHM 2046 or CHM 2096 with minimum grades of C.
Consists of classroom lectures on fundamental concepts in magnetism and magnetic micro and nano-materials and their applications in biomedicine. Participants present a critical review of recent literature in the field and lead a group discussion on a specific, recent paper.

BME 6324 Stem Cell Engineering
Credits: 3; Corequisite: Undergraduate cell biology and molecular biology and physiology, or enrollment in the Biomedical Engineering graduate program, or consent from instructor.
Including an historical review of stem cell research and policies surrounding stem cell research, current stem cell sources, strategies and reviews of current stem cell research. This information is essential for Biomedical Engineers to understand in repairing/rebuilding the human body after injury or disease using stem/progenitor cell strategies.

BME 6330 Cell and Tissue Engineering
Credits: 3; Prerequisite: GMS6421, *BME 5001, or consent of instructor.*
Applying engineering principles, combined with molecular cell biology, to developing a fundamental understanding of property-function relationships in cells and tissues. Exploiting this understanding to manipulate cell and tissue properties rationally to alter, restore, maintain, or improve cell and tissue functions; and to design bioartificial tissue substitutes.

BME 6938 Advanced Tissue Engineering*
Credits: 3.
This course will cover engineering and biological principles behind tissue and organ regeneration - and the challenges facing the filed. The course covers basic and advanced principles, combined with molecular and cellular biology, in an effort to develop fundamental understanding of these challenges and approaches that may overcome them. We will focus on angiogenesis and systems that aid nutrient transport within engineered organs with the continuing goal to restore function as we progress toward creating fully function neo-organs.
**Special topics course – not offered every term.*

EGN 4912 Engineering Undergraduate Research
Credits: 0-3.
The primary purpose of this course is to provide the student an opportunity for firsthand, supervised research. “Research” is defined as mentored, but self-directed, work that enables individual students or a small group of students to explore an issue of interest to them and to communicate the results to others. Projects may involve inquiry, design, investigation, scholarship, discovery, or application, depending on the topic, and the student is aware of how her or his project fits into and contributes to solving the larger problem to which it belongs. The student will usually assist a faculty member with a research project by helping to prepare the study and contributing in a meaningful way in meeting the objectives

of the study. The student may work with a graduate student who is performing research supervised by a research faculty member.

EMA 3066 Introduction to Organic Materials
Credits: 3; Prerequisite: EMA 3010 and one of the following: EMA 3011, CHM 2200 or CHM 2210.
Uses, structure, processing and properties of organic materials, including polymers, biomacromolecules and small molecule organic materials. Scientific principles are introduced through discussion of developed organic materials for high technology applications.

EMA 3413 Introduction to Electronic Materials
Credits: 3; Prerequisite: EMA 3010.
Atomistic and quantum-mechanical description of the electrical, optical, magnetic and thermal properties of materials. Deals with metals, alloys, semiconductors, polymers, dielectrics and amorphous materials with special emphasis given to high technology applications of electronic materials.

EMA 4061 Biomaterials: Structure & Properties
Credits: 3; Corequisite: EMA 3066.
Materials commonly used for biomedical application, such as their properties from a biocompatibility or medical device perspective. In addition, materials interactions with biological systems are examined from the molecular (e.g., protein), cellular, tissue and systemic (whole body) perspective. This is the foundation for the second biomaterials class, which applies these principles toward the application of biomaterials in medical implants, prostheses and devices, along with the regulatory issues associated with biomaterials development.

EMA 4062 Biopolymers
Credits: 3; Prerequisite: EMA 3066.
Polymer manufacturing processes and biochemical/biophysical behavior are considered from the perspective of achieving those properties needed for the engineering of polymeric implants and devices. Unique economic, ethical and regulatory issues are also presented.

EMA 4161 Physical Properties of Polymers
Credits: 3; Prerequisite: EMA 3066 and EMA 3513C.
Molecular structure and the physical property relationships for polymers: viscoelastic behavior, the glass transition, thermomechanical and rheological properties, the crystalline and amorphous molecular solid state. Correlation of properties with design engineering of polymer applications. Laboratory section included.

EMA 6580 Science of Biomaterials
Credits: 3.
Introduction to variables that control compatibility and performance of biomaterials, including physical and chemical properties, corrosion, fatigue, and interfacial histochemical changes.

EMA 6581 Polymeric Biomaterials
Credits: 3; Prerequisite: CHM2045 or CHM2095 & EMA3066 or equivalents.
Biomedical implant and device applications of synthetic and natural polymers. Biocompatibility and interfacial properties of polymers in physiological environment, especially concerning

shortterm devices (catheters) and long-term implants (intraocular lenses, vascular and mammary prostheses, etc.).

EMA 6938 Nanomaterials: Theory to Practice*

Credits: 3.

Nanomaterials provide new and unique properties of materials not seen in the bulk. These properties can be exploited for a wide variety of applications ranging from electronics, magnetics, optics, to biomedicine. This course will cover the fundamental science behind the properties of nanomaterials. We will discuss the scaling laws of materials properties as they reach the nanometer size regime, and how these materials will drive new applications in a variety of areas.

**Special topics course – not offered every term.*

EMA 6938 Polymers in Drug Delivery*

Credits: 3.

Polymers have played a critical role in the design and application of drug delivery systems that can increase efficacy and reduce toxicity of therapeutics. This course will provide students with an understanding of the principles, strategies, and materials used in the engineering of controlled drug delivery systems. To this end, it will focus on topics at the interface between engineering and medicine such as polymer chemistry, biomaterials, mass transport, and pharmacokinetics. The course will first cover the fundamentals of drug delivery, including physiology, pharmacokinetics/pharmacodynamics, drug diffusion and permeation, and biomaterials used in drug delivery. Controlled release strategies for various administration routes will then be discussed. The course will conclude with special topics lectures from graduate students.

**Special topics course – not offered every term.*

Biomechanics

Biomechanics is the study of engineering mechanics in biological and medical systems. Biomechanics spans multiple scales, including the mechanics of whole body motion, the functional properties of living tissues, and the migration and mechanics of cells. Biomedical engineers with a focus on biomechanics can work across several medical disciplines, applying mechanics to the study movement disorders, implant design, tissue engineering, and rehabilitation therapy, amongst others. For more information: American Society of Biomechanics website, International Society of Biomechanics website.

To stay on schedule for this track, student must complete EGM2511 Engineering Mechanics: Statics before enrolling in the fall semester of their junior year. Otherwise, students will have difficulty completing the requirements by the spring semester of their junior year.

Engineering courses (at least 3 required):

BME 4931 Biomedical Engineering for Global Heath*
Credits: 3.
This course will broaden understanding of global health concerns and how healthcare technologies can play a role in improving human health in developed and developing regions. The course will cover global health demographics and comparative health systems, plus selected major health problem areas. Basic quantitative and design principles of biomedical engineering as well as introductory epidemiology principles will be covered, and examples will highlight of the impact of biomedical technology on global health. Legal, ethical and cultural issues associated with developing and disseminating new medical technologies will be considered. Topics will be taught at the sophomore level, and to be accessible to non-engineering students and beginning engineering students.
**Special topics course – not offered every term.*

BME 4931 Mechanics of Biomaterials and Tissue*
Credits: 3.
This course covers how biomaterials and tissue respond to mechanical loads and stress. The course will first review the basic material compositions of metals, ceramics, and polymers. The course will then focus of the response of the mechanical response of these materials to loads and stress commonly experienced in the biological environment.
**Special topics course – not offered every term.*

EGM 3401 Engineering Mechanics-Dynamics
Credits: 3; Prerequisite: EGM 2511 or EGM 2500, and MAC 2313.
Continues the dynamics sequence begun in EGM 3400 plus extended coverage of three-dimensional rigid-body dynamics and orbital motion.

EGM 4590 Biodynamics
Credits: 3; Prerequisite: EGM 3400 or EGM 3401, or instructor permission.
Dynamic analysis of the human musculoskeletal system. Includes development of lumped mass, planar rigid body and 3-D rigid body models of human movement. Also includes calculation of internal forces in muscles and joints and analysis of muscle function using dynamics principles and musculoskeletal geometry.

Approved Track Courses

EGM 4592 Bio-solid Mechanics
Credits: 3; Prerequisite: EGM 3520.
Introduction to solid and fluid mechanics of biological systems. Includes rheological behavior of materials subjected to static and dynamic loading, the mechanics of cardiovascular, pulmonary and renal systems, and the mathematical models and analytical techniques used in biosciences.

EGM 4853 Bio-fluid Mechanics and Bio-heat Transfer
Credits: 3; Prerequisite: EGN 3353C.
A study of biothermal fluid sciences with an emphasis on the physiological processes occurring in human blood circulation and the underlying mechanisms from an engineering prospective.

EGN 3353C Fluid Mechanics
Credits: 3; Prerequisite: MAC 2313, EGM 2511 and EML 3100, or EML 3007.
Statics and dynamics of incompressible fluids. Application to viscous and inviscid flows. Dimensional analysis. Compressible flow.

EGN 4912 Engineering Undergraduate Research
Credits: 0-3.
The primary purpose of this course is to provide the student an opportunity for firsthand, supervised research. “Research” is defined as mentored, but self-directed, work that enables individual students or a small group of students to explore an issue of interest to them and to communicate the results to others. Projects may involve inquiry, design, investigation, scholarship, discovery, or application, depending on the topic, and the student is aware of how her or his project fits into and contributes to solving the larger problem to which it belongs. The student will usually assist a faculty member with a research project by helping to prepare the study and contributing in a meaningful way in meeting the objectives of the study. The student may work with a graduate student who is performing research supervised by a research faculty member.

EML 4507 Finite Element Analysis and Design
Credits: 3; Prerequisite: EGM 3344, EGM 3520 and MAP 2302 with minimum grades of C.
Stress-strain analysis and design of machine elements and finite element analysis.

EML 5595 Mechanics of the Human Locomotor Systems
Credits: 3; Prerequisite: EGM 3401, 3520.
Analyzing the human musculoskeletal system as sensors, levers, and actuators. Joint articulations and their mechanical equivalents. Kinematic and kinetic analysis of human motion. Introduction to modeling human body segments to analyze human activities.
Spring

EML 5598 Orthopedic Biomechanics
Credits: 3; Prerequisite: Mechanics of Materials.
Mechanical properties of the human body’s hard and soft tissues. Mechanical and biological considerations for repair and replacement of soft and hard tissues and joints. Fracture fixation, orthopedic implants for hip and knee, and orthotic and prosthetic devices.
Fall

Approved Track Courses

<u>Math/Science courses (these do NOT fulfill the 3 engineering course requirement):</u>

APK 2100C Applied Human Anatomy with Laboratory*
Credits: 4.
Study of general anatomy of the human body from a systematic approach. Understanding anatomical terminology, gross structures, and locations of different body structures are primary concerns. Cells, tissues and organs of the integumentary, skeletal, muscular, nervous, circulatory, respiratory, digestive, urinary and reproductive systems are emphasized. (B)
<u>OR</u>
APK 2105C Applied Human Physiology with Laboratory*
Credits: 4.
Introduces body functions at the cellular, tissue, organ and systems level with emphasis on the mechanisms of operation. Designed for students interested in pursuing study in the health professions. (B)
Only one of these two 2000-level courses will count toward the Biomechanics track.

APK 3220C Biomechanical Basis of Movement
Credits: 3; Prerequisite: junior or senior standing; APK 2100C and MAC 1140 with minimum grades of C; or PHY 2048 or PHY 2053 with minimum grade of C.
Fundamentals of kinematics and kinetics related to human movement. Basics of biomechanics applied to the concepts of injury prevention and performance improvement. Overview of various biomechanical data collection and analysis.

APK 6205C Natural and Bases of Motor Performance
Credits: 3.
Principles of motor skill development, and conditions affecting motor skill development and retention in physical education activities.

APK 6225 Biomechanical Instrumentation
Credits: 3; Prerequisite: APK 6220C.
Overview of data collection and analysis tools. Hands-on experience conducting projects using EMG, videography, and force transducer technology.
Spring

GMS 5905 Biomechanics in Orthopedics and Rehabilitation*
Credits: 3.
This course will offer an interdisciplinary approach to the study of biomechanics in orthopedic clinical populations including osteoarthritis, musculoskeletal pain, athletic populations, join replacement, shoulder mechanics, balance and obesity. The clinical correlations underlying musculoskeletal disease or post-surgical conditions that impact biomechanics will be presented. Discussion of the additional functional and survey-based outcome measures that are used in parallel with biomechanical measures in the listed populations will be integrated into each class session. Participation in integrative laboratory experiences will provide opportunity to learn about motion analysis, basic joint modeling and gait measures. Development and completion of a group project is a key component of the course.
**Special topics course – not offered every term.*

PET 5936 Movement Disorders*

Credits: 3.

The course covers the sensory and motor systems of the nervous system responsible for regulating movement in movement disorders. Also covered are movement disorders including Parkinson's disease, tics, Huntington's disease, dystonia, tremor, spinal cord injury, spasticity, cerebellar disorders, and speech and language disorders. Students will be asked to attend the weekly clinical meetings at McKnight Brain Institute to see a first-hand clinical perspective of movement disorders. The course integrates motor neurons, upper motor neurons, cortical physiology of movements, basal ganglia physiology, cerebellar physiology, posture, and eye movements. Techniques used to measure movement and brain structure and function will be discussed.

**Special topics course – not offered every term.*

Spring