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): MATH 251 and MMAE 200 and BIOL 115
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* and BME 200*, 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 20181. 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 projecting 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

BME 500
Introduction to Biomedical Engineering
Introduction to the concepts and research in biomedical engineering. Provides an overview of current biomedical engineering research areas, emphasis on application of an engineering approach to medicine and physiology signals. The focus is on connecting theory with practice: students are expected to critically analyze research manuscripts and perform corresponding analysis on relevant biomedical data.
Lecture: 2 **Lab:** 0 **Credits:** 2

BME 501
Communication Skills in BME
Students will be taught to communicate biomedical engineering research findings through written, poster, and oral presentation formats. Masters of Science with Thesis and PhD program students will be required to present their own research annually at the BME Seminar while enrolled in their thesis program.
Lecture: 1 **Lab:** 0 **Credits:** 1

BME 502
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 503
Mathematical and Statistical Methods for Neuroscience I
This quarter introduces mathematical ideas and techniques in a neuroscience context. Topics will include some coverage of matrices and complex variables; eigen value problems, spectral methods and Greens functions for differential equations; and some discussion of both deterministic and probabilistic modeling in the neurosciences. Instructor permission required.
Lecture: 2 **Lab:** 0 **Credits:** 2

BME 504
Neurobiology
This course is concerned with the structure and function of systems of neurons, and how these are related to behavior. Common patterns of organization are described from the anatomical, physiological, and behavioral perspectives of analysis. The comparative approach is emphasized throughout. Laboratories include exposure to instrumentation and electronics, and involve work with live animals. A central goal of the laboratory is to expose students to in vivo extracellular electrophysiology in vertebrate preparations. Laboratories will be attended only on one day a week but may run well beyond the canonical period. Instructor permission required.
Lecture: 2 **Lab:** 0 **Credits:** 2

BME 505
Mathematical and Statistical Methods for Neuroscience II
This quarter treats statistical methods important in understanding nervous system function. It includes basic concepts of mathematical probability; information theory, discrete Markov processes, and time series. Instructor permission required.
Prerequisite(s): BME 503 with min. grade of C
Lecture: 2 **Lab:** 0 **Credits:** 2

BME 506
Computational Neuroscience II: Vision
This course considers computational approaches to vision. It discusses the basic anatomy and physiology of the retina and central visual pathways, and then examines computational approaches to vision based on linear and non-linear systems theory, and algorithms derived from computer vision.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 507
Cognitive Neuroscience
This course is concerned with the relationship of the nervous system to higher order behaviors such as perception and encoding, action, attention and learning and memory. Modern methods of imaging neural activity are introduced, and information theoretic methods for studying neural coding in individual neurons and populations of neurons are discussed. Instructor permission required.
Lecture: 2 **Lab:** 0 **Credits:** 2

BME 508
Mathematics and Statistics for Neuroscience III
This course covers more advanced topics including perturbation and bifurcation methods for the study of dynamical systems, symmetry methods, and some group theory. A variety of applications to neuroscience with be described. Instructor permission required.
Prerequisite(s): BME 505 with min. grade of C and BME 503 with min. grade of C
Lecture: 2 **Lab:** 0 **Credits:** 2

BME 509
Vertebrate Neural Systems
This lab-centered course teaches students the fundamental principles of mammation neuroanatomy. Students learn the major structures and the basic circuitry of the CNS and PNS. Students become practiced at recognizing the nuclear organization and cellular architecture of many regions in animal brain models. This course is taught at the University of Chicago. Instructor permission required.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 510
Neurobiology of Disease I
This seminar course is devoted to basic clinical and pathological features and pathogenic mechanisms of neurological diseases. The first semester is devoted to a broad set of disorders ranging from developmental to acquired disorders of the central and peripheral nervous system. Weekly seminars are given by experts in the clinical and scientific aspects of the disease under discussion. For each lecture, students are given a brief description of clinical and pathological features of a given set of neurological diseases followed by a more detailed description of the current status of knowledge of several of the prototypic pathogenic mechanisms.
Lecture: 2 **Lab:** 0 **Credits:** 2

BME 511
Extracellular Matrices: Chemistry and Biology
Advanced topics dealing with the biology and chemistry of the extracellular matrix, cell-matrix interactions, and current methodologies for engineering these interfaces.
Lecture: 2 **Lab:** 0 **Credits:** 2

BME 512
Behavioral Neurosciences
This course is concerned with the structure and function of systems of neurons and how these are related to behavior. Common patterns of organization are described from the anatomical, physiological, and behavioral perspectives of analysis. The comparative approach is emphasized throughout. Laboratories include exposure to instrumentation and electronics and work involvement with live animals.
Lecture: 2 **Lab:** 0 **Credits:** 2

BME 513
Methods of Computational Neuroscience: Single Neurons
Topics include, but are not limited to, Hodgkin-Huxley equations, cable theory, single neuron models, information theory, signal detection theory, reverse correlation, relating neural responses to behavior, and rate versus temporal codes. Instructor permission is required.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 516
Biotechnology for Engineers
This course will provide students opportunity to learn about the field of biotechnology and how to apply engineering principles to biological systems and living organisms for betterment of medicines as well as agricultural products. The course covers the introduction to biotechnology with information about cell and molecular biology, the role of enzyme and growth kinetics, media preparations for cell culture and various chromatographic techniques, and antibiotics and its role in secondary metabolic production. Biological effluent treatment and regulatory issues to obtain FDA will be taught. Instructor permission is required.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 517
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 518
Reaction Kinetics for Biomedical Engineering
This course is an introduction to the fundamentals of chemical kinetics. Analysis of rate data; 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.
Corequisite(s): BME 482
Prerequisite(s): BME 301 and MATH 252 and BME 335
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 519
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. Includes a student project.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 521
Medical Imaging
Study of modern technology for medical imaging. Theory and operation of CAT, SPECT, PET, MRI, X-ray and echo imaging modalities.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 522
Mathematical Methods in Biomedical Engineering
Graduate standing in BME or consent of instructor This course is an introductory graduate level course that 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.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 523
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. Permission of instructor is required.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 524
Quantitative Aspects of Cell andTissue 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.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 525
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 526
Advanced Biomedical Engineering Design
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. Permission from instructor is required.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 527
Extracellular Matrix Biology
This course is a the same as the BME 427 Extracellular Matrix Biology course that has been approved for banner listing for Summer 2020. BME527 is the same class to extend this course to graduate students. 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 20181. 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: 3 **Lab:** 0 **Credits:** 3

BME 528
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 530
Inverse Problems in Biomedical Imaging
This course will introduce graduate students to the mathematical theory of inverse problems. Concept from functional analysis will be applied for understanding and characterizing mathematical properties of inverse problems. This will permit for the analysis of the stability and resolution of image reconstruction algorithms for various existing and novel biomedical imaging systems. The singular value decomposition (SVD) is introduced and applied for understanding fundamental properties of imaging systems and reconstruction algorithms. Instructor permission required.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 532
Medical Imaging Science
This course is an introduction to basic concepts in medical imaging, such as: receiver operating characteristics, the rose model, point spread function and transfer function, covariance and auto covariance, noise, filters, sampling, aliasing, interpolation, and image registration. Instructor permission required.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 533
Biostatistics
This course is designed to cover the tools and techniques of modern statistics with specific applications to biomedical and clinical research. Both parametric and nonparametric analysis will be presented. Descriptive statistics will be discussed although emphasis is on inferential statistics and experimental design.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 535
Magnetic Resonance Imaging
This is an introduction to the Physics and technology of magnetic resonance imaging (MRI). the topics that are covered include: basic MR physics, source of signal, signal acquisition, pulse sequences, hardware, artifacts, spectroscopy, and advanced imaging techniques. Instructor permission required.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 537
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.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 538
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 (MEG) and studying brain function with MEG. The second part of the deals with brain connectivity. It includes an introduction to diffusion tensor MRI, explanation of the relationship between the diffusion properties of tissue its structural characteristics, and white matter fiber tractography techniques. Instructor permission required.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 539
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.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 540
Wave Physics and Applied Optics for Imaging Scientists
This course will introduce students to fundamental concepts in wave physics and the analysis of optical wave fields. These principles will be utilized for understanding existing and novel imaging methods that employ coherent radiation. Solutions to inverse scattering and inverse source problems will be derived and algorithmic realizations of the solutions will be developed. Phase contrast imaging techniques and X-ray imaging systems that employ coherent radiation will be studied. Instructor permission required.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 542
Advanced Concepts in Image Science
This graduate level course introduces students to fundamental concepts in image science that are related to the optimization and evaluation of biomedical imaging systems. Topics covered include: deterministic descriptions of imaging systems, stochastic descriptions of imaging systems, statistical decision theory, and objective assessment of image quality.
Prerequisite(s): BME 532 with min. grade of C and BME 530 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 543
Bioinstrumentation and Electronics
Principles of circuit analysis are applied to typical transducer and signal recording situations found in biomedical engineering. Basic electrical and electronic circuit theory is reviewed with an emphasis on biomedical measurement applications. a special topic is individually studied by the student and presented to the class electrical physics class or basic circuits.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 545
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 with min. grade of C or BME 553* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 551
Physiological Signal Processing and Control Theory
This is the first of a 2 part course co-taught at IIT and the University of Chicago. essential elements of signal processing and control theory as it is applied to physiological systems will be covered. Part I will cover data acquisition and sampling, Laplace and Fourier transforms, filtering, time and frequency domains, system descriptions and lumped vs. distributed parameters. Students will use Mat lab to test concepts presented in class.
Lecture: 2 **Lab:** 0 **Credits:** 2

BME 552
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.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 553
Advanced Quantitative Physiology
The main systems that control the human body functions will be reviewed to enable the students to understand the individual role of each major functional system as well as the need for the integration or coordination of the activities of the various systems.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 560
Methods in Biomedical Data Science
The course provides an overview of predictive and descriptive statistical modeling methods for large biomedical datasets. Building on undergraduate-level knowledge of statistics, the course introduces Bayes and information theory, develops from these modeling algorithms and provides a series of biomedical application areas. Methods include meta-analytic techniques, linear and non-linear dimensionality reduction, traditional “non-deep” predictive tools (e.g. perceptron, support vector machines, logistic regression, decision trees, boosting, etc.), and some applications of deep neural networks. Application areas may include medical imaging (e.g. image segmentation), EEG and ECG signal analysis (e.g. anomaly detection), genetics (e.g. imputation methods, polygenic risk score computation, cell-free DNA analysis, etc.). Each course module involves analysis of real data using existing modeling libraries and students’ own implementation. The predictive results may be compared to the state-of-the-art for each example dataset to assess the usefulness of the models. (3-0-3)
Prerequisite(s): (MATH 225 or BME 433 or CHE 426) and (MATH 332 or MATH 333)
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 575
Neuromechanics of Human Movement
This course will explore how we control movement of our extremities, with concepts drawn from mechanics and neurophysiology. The progression from neurological signals to muscle activation and resulting movement of the hand or foot will be modeled, starting at the periphery and moving back toward the central nervous system. Biomechanics of the limbs will be modeled using dynamic simulation software (Working Model) which will be driven by a neural controller, implemented in MATLAB. Issues related to sensory feedback and redundancy will be addresses.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 581
Fluid Mechanics for Biomedical Engineers
This course is primarily focused on the development of theoretical and experimental principles necessary for the delineation of fluid flow in various in vitro chambers and the cardiovascular system. Its content will primarily deal with the basic concepts of flow in various geometries, the heterogeneous nature of blood and the application of such principles in flow chambers designed to expose blood elements to defined flow conditions. The relationship to flow in the normal and diseased vascular system will also be considered. A basic Fluid Dynamics Course is recommended. Instructor permission required.
Prerequisite(s): BME 500 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 582
Advanced Mass Transport for Biomedical Engineers
This course is primarily focused on the development of theoretical and mathematical principles necessary for the delineation of mass transport processes in biological & medical systems. The content includes heterogeneous reactions that occur at or in the vicinity of cells or vascular structures under applied laminar flow and transport across cell membranes and within tissues.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 585
Computational Models of the Human Cardiovascular System
This course will focus on the use of computational fluid dynamics for the modeling and analysis of the human cardiovascular system. The course will cover both computational methods for fluid dynamics and biomedical aspects of the human cardiovascular system. Computer models for the simulation and analysis of hemodynamic phenomena will be developed. Requires an Introductory fluid dynamics.
Lecture: 3 **Lab:** 0 **Credits:** 3

BME 591
Research and Thesis for Master of Science Degree
Research and thesis for master of science degree students. Instructor permission required.
Credit: Variable

BME 594
Special Projects
Special projects.
Credit: Variable

BME 595
Seminar in Biomedical Engineering
Current research and development topics in biomedical engineering as presented by outside speakers, faculty and advanced students.
Lecture: 0 **Lab:** 1 **Credits:** 1

BME 597
Special Problems
Special problems.
Credit: Variable

BME 691
Research and Thesis PHD
Research and Thesis for PhD degree. (variable credit)
Credit: Variable