Biomedical Engineering

Phone:	314-935-7208
Website:	https://bme.wustl.edu/academics/undergraduate-programs/index.html

Courses

BME 1400 Introduction to Biomedical Engineering
An introduction to the vast and diverse field of biomedical engineering (BME), this very challenging course has two main purposes. One is to teach students -- via lectures, reading assignments, homework and exams, to think on their own, to solve problems and know how engineering principles are applied to the areas of bioelectricity, biomechanics, biomolecules, biotechnology and bioimaging. The second is to introduce students -- via guest lectures by school of medicine and engineering faculty, to some of the fascinating and challenging ongoing research in these areas. The course is challenging because students at this early stage, by and large, lack the knowledge base to understand either the engineering / biological aspects of the topical areas or the research being presented. Nevertheless, because future success depends on such, emphasis throughout is placed on developing self-learning as well as quantitative and analytical problem-solving skills, but at an appropriate level. By the end of the course it is hoped that students will have begun to acquire the skills and approaches necessary to succeed in the engineering curriculum as well as a much more in-depth and informed perspective of BME.
Credit 3 units.
Typical periods offered: Fall

BME 2200 Introduction to Biomedical Circuits
Electricity is central to normal and abnormal biological function, spanning scales from the subcellular to whole systems. Scientists and engineers also use electrical engineering to design and implement interaction with biological tissue, from classical physiological experiments to cutting-edge brain-computer interfaces. This course will begin the study of bioelectrical engineering by introducing simple electrical elements, circuits, amplifiers, and instrumentation. Relevant biological examples and computer modeling will be used throughout. The lab component will provide hands-on laboratory practice with simple electrical elements, circuits, amplifiers, instrumentation, and computer modeling, with a focus on biomedical applications. BME 220 fulfills the circuits requirement for BME students in place of ESE 230.
Credit 4 units.
Typical periods offered: Fall, Spring

BME 2201 Biomedical Circuits Laboratory
This course covers the lab portion only of E62 BME220. It is open only to those students who have completed an approved lecture-only circuits course and who need to fulfill the circuits lab requirement for the BS-BME degree.
Credit 1 unit.
Typical periods offered: Fall, Spring

BME 2310 Foundations of Biomedical Computing
This elective course provides a basis for solving problems in biomedical engineering through coding and computation. Coding structures applied to concepts in linear algebra, statistics, and probability are introduced as a foundation to more advanced biomedical data science applications in machine learning and artificial intelligence. The course is taught using Python; no prior knowledge of Python is expected or required. Students should be comfortable with high school level algebra and geometry. This course is required as prerequisite for BME440, Biomedical Data Science, and is a required course for the Biomedical Data Science minor.
Credit 3 units.
Typical periods offered: Spring

BME 2400 Biomechanics
Principles of static equilibrium and solid mechanics applied to the human anatomy and a variety of biological problems. Statics of rigid bodies with applications to the musculoskeletal system. Mechanics of deformable media (stress, strain; stretching, torsion, and bending) with introduction to nonlinear behavior, viscoelasticity, and growth in living tissue. Applications to cells, bone, muscle, arteries, the heart, and the cochlea.
Credit 3 units.
Typical periods offered: Fall, Spring

BME 2401 Biomechanics Laboratory
This course will consist of hands-on laboratory experiments in topics relevant to bioengineering mechanics such as statics of rigid bodies, viscoelasticity, and stress/strain analysis of biological materials. A focus of the course will be extending fundamental mechanical principles to biological applications through experimentation. The course is designed to follow and enhance the material covered in BME 240. Additionally, students will have the opportunity to design their own experiments, explore topics of special interest, and present their findings.
Credit 1 unit.
Typical periods offered: Fall, Spring

BME 3010 Quantitative Physiology I
A course (lectures, recitation and supervised laboratory sections) designed to elaborate the physiological background necessary for advanced work in biomedical engineering. A quantitative model-oriented approach to physiological systems is stressed. Topics include bioinstrumentation, eye movement, muscle mechanics, action potentials, sensory systems, neuroprosthetics.
Credit 4 units.
Typical periods offered: Fall

BME 3015 Quantitative Physiology II
A course (lecture and supervised laboratory sessions) designed to elaborate the physiological background necessary for advanced work in biomedical engineering. A quantitative model-oriented approach to physiological systems is stressed. Topics include electrocardiography; heart contractility and molecular bases; cell signaling, pulse wave propagation in arteries; pulmonary function; renal function; imaging, and systems biology. immune system; drug delivery.
Credit 4 units.
Typical periods offered: Spring

BME 3200 Bioengineering Thermodynamics
This course covers the foundations of thermodynamics with strong emphasis on concepts and the translation of concepts. Topics to be covered include the first and second laws of thermodynamics, probabilistic descriptions of entropy, consequences of the first and second laws in ideal and non-ideal single- and multicomponent systems, free energies as descriptors of equilibria in laboratory and biological systems, chemical equilibria, phase equilibria, treatment of aqueous solvents and mixtures, colligative properties, thermodynamics of protein folding, and protein binding equilibria. The material,

the lectures, and the homeworks emphasize learning that enables the translation of concepts into mathematical analysis. A strong background in differential calculus of multiple variables and differential equations (Math 217) is required. Emphasis is placed on regular homeworks and working in collaborative groups. The main textbook for the course will be Molecular Driving Forces: Statistical Thermodynamics in Chemistry and Biology, 2nd edition by Ken A. Dill and Sarina Bromberg published by Garland Science. The lectures and course notes will also draw on other sources including the classical book by Herbert Callen. A weekly recitation section will be offered. Students are strongly urged to attend lectures and the recitation section.
Credit 3 units.

Typical periods offered: Fall

BME 3290 Biothermodynamics in Practice
This course will include hands-on, laboratory experiments in topics relevant to bioengineering thermodynamics, such as heat transfer, relationships involving temperature and pressure, equilibria, mixing, and solution chemistry. A focus of the course will be extending fundamental scientific principles to biological applications. Students will have the opportunity to design their own experiments, explore topics of special interest, and present their findings.
Credit 3 units.

Typical periods offered: Spring

BME 3660 Transport Phenomena in Biomedical Engineering
Many processes of importance in biology and medicine involve the transfer of mass, heat or momentum. Through the use of the differential control volume approach, the fundamental transport equations will be derived. Systematic derivation of differential equations appropriate for different types of transport problems will be explored. Solutions of the resulting differential equations for simple chemical/biological systems will then be sought. Macroscopic descriptions of fluid flow will be applied to the design of blood pumps for the heart. Unsteady mass transfer with diffusion, advection and chemical reactions will also be applied to the transport of proteins, metabolites and therapeutics throughout the body.
Credit 3 units.

Typical periods offered: Fall, Spring

BME 4000 Independent Study
Independent investigation on topic of special interest. This course has no engineering topics units. Approval of the BME Undergraduate Studies Committee is required for enrollment.
Credit 6 units.

Typical periods offered: Fall, Spring

BME 4001 Independent Study
Independent investigation on a topic of special interest. This course has 1 unit of engineering topics. The student and mentor must justify the number of engineering topic units being requested and the BME Undergraduate Studies Committee must approve the requested number of engineering topics. Approval of the BME Undergraduate Studies Committee is required for enrollment.
Credit 1 unit.

Typical periods offered: Fall, Spring

BME 4002 Independent Study
Independent investigation on a topic of special interest. This course has 2 units of engineering topics. The student and mentor must justify the number of engineering topic units being requested and the BME Undergraduate Studies Committee must approve the requested number of engineering topics. Approval of the BME Undergraduate Studies Committee is required for enrollment.
Credit 2 units.

Typical periods offered: Fall, Spring

BME 4003 Independent Study
Independent investigation on a topic of special interest. This course has 3 units of engineering topics. The student and mentor must justify the number of engineering topic units being requested and the BME Undergraduate Studies Committee must approve the requested number of engineering topics. Approval of the BME Undergraduate Studies Committee is required for enrollment.
Credit 3 units.

Typical periods offered: Fall, Spring

BME 4021 Biomedical Data Science Capstone Design
Previously described as BME 401DS. This course provides a client-centered design experience in biomedical data science. Students will work as individuals or in small teams with possible clients to define and scope an unmet need in biomedical data science. The students will work on an original solution or a redesign of an existing solution to address the unmet need. The design experience will involve application of knowledge and skills acquired in earlier coursework. It will also incorporate best practices in biomedical data science, including ethical considerations such as respect for persons, social license, and vulnerabilities; patient safety and privacy; and HIPAA compliance. Students will be guided through the design process and will produce and present appropriate deliverables for their project. This course is required for the Biomedical Data Science minor.
Credit 3 units.

Typical periods offered: Spring

BME 4100 Service Learning Experience in Guangdong and Hong Kong
This pass/fail course is a 2-week international service-learning experience in conjunction with the faculty and students of our partner, Department of Biomedical Engineering at the Hong Kong Polytechnic University (PolyU). During the summer, students first attend an orientation at PolyU to learn about functional electrical stimulation (FES) and treating cerebral palsy with orthotic devices. The entire group then goes to a clinic in mainland China where they put into practice what they have learned, the former in patients who have suffered strokes and the latter in children with cerebral palsy - working in teams to diagnose, fit and fabricate orthotic devices. A written summary of the experience is the final product. Academic credits are awarded at the end of the fall semester following the summer experience.
Credit 2 units.

Typical periods offered: Spring

BME 4320 Physics of Biopolymers
This course will cover physics concepts from the statistical physics of polymers and polymer solutions to describe proteins, nucleic acids, and bioinspired polymers. Topics include statistical physics concepts, theoretical and numerical descriptions of polymers, applying these descriptions to biopolymers, the thermodynamics of polymer solutions, concepts of polymer dynamics, descriptions of polymeric materials and advanced topics in phase transitions and molecular design. The material will be fast-paced and involve rigorous mathematical descriptions, experimental design, interpretations of experimental data, and some numerical simulations. The course will be heavy on individual homework and team-based project work. Direct connections between concepts and modern topics in biology and biomaterials will be emphasized.
Credit 3 units.

Typical periods offered: Fall, Spring

BME 4330 Biomedical Signal Processing
An advanced undergraduate/graduate level course. Continuous-time and discrete-time application of signal processing tools to a variety of biomedical problems. Course topics include linear systems theory, frequency transforms, sampling theorem, basis functions, linear filtering, feature extraction, noise analysis, system identification. Concepts learned in class will be applied using software tools to real biomedical signals such as speech, ECG, EEG, medical images.
Credit 3 units.
Typical periods offered: Spring

BME 4400 Biomedical Data Science
This course will cover data analysis, statistical methods, AI, machine learning, predictive modeling, and data visualization, with applications to medicine and health. As part of the course, BME faculty will present biomedical data science topics from their research areas. Students will learn to prepare, transform, visualize, validate, model, and communicate information about datasets, and they will design and implement an independent project to address a biomedical data science problem. Prior Python experience required.
Credit 3 units.
Typical periods offered: Fall

BME 4420 Biomacromolecules Design and Engineering
Biological macromolecules (i.e., carbohydrates, lipids, proteins, and nucleic acids) are important components of the cell and its supporting matrix that perform a wide array of functions. This course will introduce the principles and recent advances in nucleic acid/gene engineering, protein/peptide engineering, and chemical/enzymatic conjugation technologies; it will also discuss the application of engineered biomacromolecules in clinical therapeutics/diagnostics, biosensing, bioimaging, and biocatalysis. Students will learn material through lectures, reading, homework, scientific publications, and molecular visualization tools. Students will work individually or in pairs/groups to develop and lead discussions on engineering biomacromolecules and molecular characterization techniques.
Credit 3 units.
Typical periods offered: Spring

BME 4710 Bioelectric Phenomena
This course is a quantitative introduction to the origins of bioelectricity, with an emphasis on neural and cardiac electrophysiology. Topics will include electric fields and current flow in volume conductors; cell membrane channels and their role in generating membrane potentials; and action potentials and their propagation in myelinated and unmyelinated axons as well as cardiac tissue. Minor topics of discussion will include both skeletal muscle and non-human (e.g., electric fish) sources of bioelectricity.
Credit 3 units.
Typical periods offered: Fall

BME 4736 Biomedical Engineering Entrepreneurship
Students will learn about entrepreneurship, including IP, business development, and fundraising, through case studies.
Credit 3 units.
Typical periods offered: Fall

BME 4790 Biofabrication & Medical Devices
This course will cover materials design and modern manufacturing methods for biofabricated tissues and medical devices (with a particular emphasis on bioelectronic devices). Topics will include additive manufacturing and their materials requirements along with how these methods have evolved to use biomaterials and cells, such as bioprinting. State-of-the-art in vitro and implantable devices for diagnostic and therapeutic purposes will be discussed with emphasis on how their properties have advanced from developments in materials and manufacturing. Lecture material and assignments will draw from both current market devices and the clinical standard-of-care as well as ongoing research and recent scientific literature. Registration will be split between undergraduate and graduate students.
Credit 3 units.
Typical periods offered: Fall

BME 4960 Design and Development of Optical Imaging Systems
In this course, students will learn the design principles of optical imaging systems and learn to use optical simulation software, such as ZEMAX/OpticsStudio. There is also hands-on imaging system development components that will allow students to practice skills developed to make prototype imaging systems.
Credit 3 units.
Typical periods offered: Fall

BME 4970 Senior Capstone Design a
A hands-on design experience to provide students practical application of engineering. Working in small teams, students will either meet with possible clients to discern a biomedical problem, or bring an original idea of their own to the class. The students will work on an original design or redesign of a component or system of biomedical engineering significance. The students will be taught how to craft a project scope with the required design specifications. The design experience will require application of knowledge and skills acquired in earlier coursework; it will incorporate engineering standards and realistic constraints that include most of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, FDA, social, and political. Students will prepare written reports and present their designs orally to a panel of faculty members and industrial representatives. The final product of BME 401A will be a descriptive paper design of their solution.
Credit 2 units.
Typical periods offered: Fall

BME 4971 Senior Capstone Design B
A hands-on design experience to provide students practical application of engineering. Working in small teams, students will work towards building a prototype of the student design which was a product of 401A. The students will be expected to design a verification and validation plan to test the prototype built. The design experience will require application of knowledge and skills acquired in earlier coursework and lab experiences; it will incorporate engineering standards and realistic constraints that include most of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, FDA, social, and political. Students will prepare written reports and present their designs orally to a panel of faculty members and industrial representatives. The final product of BME 401B will be a prototype, and a descriptive paper describing their solution documenting how the prototype satisfies the design specifications, with the validation and verification results.
Credit 2 units.
Typical periods offered: Spring

BME 4980 Biomedical Engineering Design
A design project experience to prepare students for engineering practice. Working individually or in small groups, students will undertake an original design or redesign of a component or system of biotechnological significance. The design experience will require application of knowledge and skills acquired in earlier classes and laboratory work; it will incorporate engineering standards and realistic constraints that include most of the following considerations: economic, environmental, ethical, manufacturability, sustainability,

health and safety, social and political. Students will prepare written reports and present their designs orally to their classmates and panels of faculty members and industrial representatives. Prototype construction is not generally required but may be encouraged subject to available time, financial and material resources.
Credit 4 units.

Typical periods offered: Fall

BME 4981 Senior Design II
BME 402 is a continuation of BME 401. Working in small groups, students will take a paper design completed in BME 401 and build a prototype. They will evaluate, optimize, and undertake the building of the design. The design experience will require the application of knowledge and skills acquired in earlier course work; it will incorporate engineering standards and realistic constraints that include most of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, social and political. Students will prepare written reports and participate in oral design reviews involving a panel of faculty members and industrial representatives. Prototype construction is the final goal of the class.
Credit 1 unit.

Typical periods offered: Spring

BME 4999 Independent Study
Undergraduate independent study.
Credit 3 units.