

# Biomedical Engineering (BME)

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## **BME 2000: Professional Development in Engineering**

(same as BIOL\_EN 2000). A review of professional opportunities, registration, ethics, and societies. Graded on A-F basis only.

**Credit Hours:** 2

**Prerequisites:** Sophomore standing

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## **BME 2001: Topics in Biomedical Engineering**

Current and new technical developments in biological engineering. Graded on A-F basis only.

**Credit Hour:** 1-5

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## **BME 2017: World of Neuroscience**

(same as BIOL\_EN 2017, CMP\_SC 2017, ECE 2017, BIO\_SC 2017). This in-class course will introduce undergraduates to the growing area of neuroscience from the perspectives of three disciplines: engineering, biology and psychology. Topics in the course will span multiple levels of neuroscience including genomic, genetic, molecular, cellular, systems, behavioral and clinical levels. Due to the interdisciplinary nature of the neuroscience, the classes will cover diverse topics. The topics will range from overviews of the key neurobiology areas, to lab sessions involving how to analyze your own brain signals (EEG), and to visits to brain imaging center and EEG lab. The overall goal is to provide a broad exposure to the fascinating world of interdisciplinary neuroscience. Graded on A-F basis.

**Credit Hour:** 1

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## **BME 2070: Cell and Molecular Biology for Engineers**

(same as BIOL\_EN 2070). This course will build a solid foundation of cell and molecular biology for engineering students pursuing careers in biomedical and biological engineering. Students will not only be introduced to the concepts, structures, principles, and mechanisms of living systems at the cellular and molecular level, but will also learn how engineering and biological principles come together to develop practical applications to advance medicine and bioresource utilization. Graded on A-F basis only.

**Credit Hours:** 4

**Prerequisites:** BIO\_SC 1500, CHEM 1320, and MATH 1500

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## **BME 2080: Introduction to Programming for Engineers**

(same as BIOL\_EN 2080). This course teaches how to write scientific programs for analysis of data and simulation of physical phenomena using MATLAB. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** MATH 1500

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## **BME 2180: Engineering Analysis of Bioprocesses**

(same as BIOL\_EN 2180). Material and Energy Balances. Integrating principles of physics, chemistry and mathematics to analyze steady state and transient biological/biomedical processes. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** MATH 1700, CHEM 1320, PHYSCS 2750

**Recommended:** 2080

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## **BME 3001: Topics in Biomedical Engineering**

Current and new technical developments in biomedical engineering. Graded on A-F basis only.

**Credit Hour:** 1-5

**Prerequisites:** Instructor's Consent

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## **BME 3070: Biological Fluid Mechanics**

(same as BIOL\_EN 3070). Basic principles of fluid mechanics applied to transport processes in biological systems. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** PHYSCS 2750 and MATH 1700

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## **BME 3075: Introduction to Materials Engineering**

(same as BIOL\_EN 3075, CH\_ENG 3075). Course covers concepts and techniques in materials engineering from an engineering design perspective, materials requirements for design, and fundamentals; intended for undergraduate engineering students. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites or Corequisites:** One of the following BIOL\_EN 3180, BME 3180, CH\_ENG 3234, MAE 4231, MAE 4300, or instructor consent

**Prerequisites:** MATH 2300, ENGINR 1200, or instructor's consent

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## **BME 3170: Biomaterials**

(same as BIOL\_EN 3170). Engineering sciences and design will be leverage for the study and design of biomaterials. Understanding the structure-property relationship between biomaterials and tissue will be addressed for implant design. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites or Corequisites:** BIOL\_EN 2180, ENGINR 2200, or instructor's consent

**Prerequisites:** BIOL\_EN 3075 or BME 3075

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**BME 3170W: Biomaterials - Writing Intensive**

(same as BIOL\_EN 3170W). Engineering sciences and design will be leverage for the study and design of biomaterials. Understanding the structure-property relationship between biomaterials and tissue will be addressed for implant design. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites or Corequisites:** BIOL\_EN 2180, ENGINR 2200, or instructor's consent

**Prerequisites:** BIOL\_EN 3075 or BME 3075

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**BME 3180: Heat and Mass Transfer in Biological Systems**

(same as BIOL\_EN 3180). Principles of heat and mass transfer and their applications in biomedical, bioenvironmental, and bioprocessing engineering. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites or Corequisites:** ENGINR 2300 or CH\_ENG 3261

**Prerequisites:** BIOL\_EN 2180 or CH\_ENG 2225

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**BME 4001: Topics in Biomedical Engineering**

Current and new technical developments in biomedical engineering.

**Credit Hour:** 3-9

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**BME 4002: Scientific Discovery Leading to Life Science Innovations**

The overarching goal of this course is to introduce the concept of biomedical innovation and the pathways to succeed in drug or device product development. The importance of identifying appropriate unmet clinical needs, understanding stake holder perspectives, recording and protecting their ideas, and the commercialization potential of a product will be explained. The recent, innovation-based, life science research that is carried out in academic institutions, as well as the pathways involved in translating those fundamental discoveries into products and services that affect healthcare, will be explained. We will provide an outline about drug-discovery, device development, intellectual property protection, conflict of interests, ethical perspectives, and regulatory issues, as well as the transitions from initial discovery concepts to product development. An introduction to essential disciplines and interactions that enable scientific discoveries to move forward into novel drug and device development will be provided. Graded on A-F basis only.

**Credit Hours:** 3

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**BME 4003: Design and Development of Biomedical Innovation**

The overarching goal of this course is to help participants understand the design and development (drug or device) process in biomedical innovation. This course will help participants to understand the process of choosing unmet clinical needs, articulate a need statement without integrating solution, design and develop a solution. Participants will learn to assess the commercial potential of clinical needs by performing market analysis and valuing customer needs. A conceptual understanding about development of a prototype for a device and also drug development by

different brainstorming process will be provided. Details of regulatory, reimbursement, patenting process required for product development will be explained with examples. An overview about how to evaluate preliminary designs, define product specifications, comply with manufacturing principles and methods, costs, cGMP requirements will be explained. Quality control and Quality assurance necessities for drug/device will be elucidated with case studies. Participants will gain knowledge about different business models for drug and devices, estimate market penetration and how to make profitable, patient-driven products. Graded on A-F basis only.

**Credit Hours:** 3

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**BME 4004: Regulatory Issues in Clinical Trials**

The overarching goal of this course is to help participants understand the essentials of compliance issues as it is related to conducting clinical trials using drugs and devices that have been or yet to be approved by FDA. This course will also help biomedical innovators recognize the importance of Human Subject Protection (HSP) and abide by the FDA regulations to conduct clinical trials with the new drugs/devices that are being designed to advance patient-care. The course will describe regulatory standpoints for human subject protection, how to obtain approvals and develop clinical protocols for conducting clinical trials. An overview about clinical epidemiology, biostatistics and data management and analysis will be provided. Graded on A-F basis only.

**Credit Hours:** 3

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**BME 4075: Brain Signals and Brain Machine Interfaces**

(same as BIOL\_EN 4075; cross-leveled with BIOL\_EN 7075). The course introduces state-of-the-art technologies for monitoring and manipulating brain activity, as well as the design principles of modern brain-machine interfaces (BMIs) for interacting with the brain in health and disease. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** instructor's consent

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**BME 4085: Problems in Biomedical Engineering**

Supervised independent study at the undergraduate level.

**Credit Hour:** 1-5

**Prerequisites:** instructor's consent

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**BME 4170: Biomaterials Interfaces of Implantable Devices**

(same as BIOL\_EN 4170; cross-leveled with BIOL\_EN 7170). This course introduces students to implantable devices and tissue engineering and the effects of biocompatibility of the performance of the devices and tissue engineered scaffolds. A number of implantable devices will be studied including VADs (ventricular assist devices), drug delivery systems and tissue engineered constructs/scaffolds. Special emphasis is placed on investigating the techniques to enhance biocompatibility of

the devices/scaffolds and integration of host tissue. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** BIOL\_EN 3170

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**BME 4360: Biomanufacturing Technologies**

(same as BIOL\_EN 4360, CH\_ENG 4360; cross-leveled with BIOL\_EN 7360, CH\_ENG 7360). This course is an introduction to biomanufacturing technologies and processes for manufacturing biological products (e.g., vaccine, antibodies, and therapeutic proteins). It mainly covers process development, unit operations, product evaluation, facilities, and regulatory compliance. It is an interdisciplinary course of biochemistry, microbiology, and engineering. The purpose of this course is to help the students acquire the knowledge of modern biomanufacturing and prepare them for rapidly growing fields in biomanufacturing. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** BIOL\_EN 2180 and BIOL\_EN 3180 (for biological engineering students) -or- CH\_ENG 2225 and CH\_ENG 3234 (for chemical engineering students) -or- Consent of instructor

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**BME 4370: Orthopaedic Biomechanics**

(same as BIOL\_EN 4370; cross-leveled with BIOL\_EN 7370). Engineering sciences will be leveraged to create a comprehensive study of orthopaedic biomechanics. The tissue mechanics of bone and soft tissue will be studied along with applying structural analysis of the musculoskeletal system. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** BIOL\_EN 3075 or BME 3075

**Recommended:** ENGINR 1200 and BIOL\_EN 3170 or BME 3170

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**BME 4375: Human Movement Biomechanics**

(same as BIOL\_EN 4375; cross-leveled with BIOL\_EN 7375). The course introduces students to musculoskeletal biomechanics and the measurement and analysis of human movement. Students will learn fundamental concepts in motor control and movement biomechanics through experimental, analytical, and computational methods. Topics covered include 3D kinematics, motion capture, kinetics, inverse dynamics, gait analysis, ground reaction forces, electromyography, muscle and tendon mechanics, and human movement applications including sport biomechanics and injury. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** MAE 2600

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**BME 4380: Applied Electronic Instrumentation**

(same as BIOL\_EN 4380; cross-leveled with BIOL\_EN 7380). Fundamental concepts and theories, basic electronics, analog and digital circuits, signal conditioning, computer interfacing, measurement

principles and techniques used in developing computer-based instrumentation systems. Graded on A-F basis only.

**Credit Hours:** 4

**Prerequisites:** PHYSCS 2760

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**BME 4420: Introduction to Biomedical Imaging**

(same as BIOL\_EN 4420, PHYSCS 4420; cross-leveled with BIOL\_EN 7420, PHYSCS 7420). This course offers a broad introduction to medical imaging. Topics to be covered include the physics basics and instrumentation of X-ray CT, PET, SPECT, ultrasound, MRI and Optical Imaging, as well as recent developments in biomedical imaging.

**Credit Hours:** 3

**Prerequisites:** PHYSCS 2760

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**BME 4470: Biomolecular Engineering and Nanobiotechnology**

(same as BIOL\_EN 4470; cross-leveled with BIOL\_EN 7470). Generation of biotechnological products, devices through integration of engineering approaches with contemporary biology, chemistry and nanotechnology starting at the molecular level. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** MATH 1700, PHYSCS 2760, CHEM 2100

**Recommended:** Senior/graduate standing or instructor's consent

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**BME 4470H: Biomolecular Engineering and Nanobiotechnology - Honors**

(same as BIOL\_EN 4470H; cross-leveled with BIOL\_EN 7470). Generation of biotechnological products, devices through integration of engineering approaches with contemporary biology, chemistry and nanotechnology starting at the molecular level. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** MATH 1700, PHYSCS 2760, CHEM 2100. Honors eligibility required

**Recommended:** Senior/graduate standing or instructor's consent

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**BME 4480: Physics and Chemistry of Materials**

(same as BIOL\_EN 4480, PHYSCS 4190, NU\_ENG 4319, CHEM 4490; cross-leveled with BIOL\_EN 7480, PHYSCS 7190, CHEM 7490, NU\_ENG 7319). Physics and Chemistry of Materials is a 3 credit hours course offered every spring semester for students from Physics, Chemistry, Engineering and Medical Departments and consists of lectures, laboratory demonstrations, two mid-term and one final exam. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** PHYSCS 2750, CHEM 1320 or equivalent, or instructor's consent

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**BME 4540: Neural Models and Machine Learning**

(same as ECE 4540, CMP\_SC 4540, BIOL\_EN 4540; cross-leveled with ECE 7540, BIOL\_EN 7540, CMP\_SC 7540). The projects-based course has three inter-linked components: (I) math models of neurons and neural networks, (II) machine learning in neuroscience, after a brief introduction to python and (III) software automation and cyberinfrastructure to support neuroscience. Extensive projects focusing on software automation and machine learning components, with brief in-class presentations. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** MATH 1500 or consent of instructor

**Recommended:** Introductory software programming, and introductory cell biology or consent of instructor

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**BME 4570: Fluorescent Imaging**

(same as BIOL\_EN 4570; cross-leveled with BIOL\_EN 7570). Principles and applications of the modern technology of fluorescent imaging. The course covers image formation in microscope; Fundamentals of fluorescence and fluorescent microscopy; Fluorescent probe and applications of molecular and cellular fluorescent imaging in life science research. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** BIO\_SC 1500, BIOL\_EN 2180

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**BME 4590: Computational Neuroscience**

(same as BIOL\_EN 4590, BIO\_SC 4590, ECE 4590; cross-leveled with BIOL\_EN 7590, BIO\_SC 7590, ECE 7590). An interdisciplinary course with a strong foundation in quantitative science for students in biological-behavioral sciences. Graded on A-F basis only.

**Credit Hours:** 4

**Prerequisites:** BIO\_SC 1010, BIO\_SC 1500; MATH 1500

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**BME 4770: Biomedical Optics**

(same as BIOL\_EN 4770; cross-leveled with BIOL\_EN 7770). Essential concepts and methods for applying optical techniques to biomedical diagnosis and therapy will be covered with major application examples being discussed.

**Credit Hours:** 3

**Prerequisites:** PHYSCS 2760

**Recommended:** BIOL\_EN 3180

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**BME 4940: Engineering Internship**

(same as BIOL\_EN 4940). Problem course following prior approved work experience. Problem selected by internship company representative, faculty problem adviser and student. Supervised by faculty problem advisor and presented in engineering report form. Graded on S/U basis only.

**Credit Hour:** 1-3

**Prerequisites:** advisor's consent

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**BME 4970: Nuclear Magnetic Resonance and Magnetic Resonance Imaging**

(same as BIOL\_EN 4970). Nuclear Magnetic Resonance (NMR) is one of the most powerful methods of investigating the structure, composition, and dynamics of atoms and molecules. It is now ubiquitous in chemistry and engineering labs, and has blossomed into one of the most successful medical imaging modalities - Magnetic Resonance Imaging (MRI). This course is an in-depth examination of the relevant physical principles behind this technology: basic spin physics, spectrometer design and implementation, what it can be used to measure, and how it is currently being used in laboratory and clinical settings. In particular, students will gain a working knowledge of basic nuclear physics, spin precession, T1 and T2 weighting mechanisms, the pulse/acquire NMR experiment, the influence of magnetic field gradients, Fourier theory and k-space, imaging principles, and the many pulse sequences currently employed in NMR/MRI research labs around the world.

**Credit Hours:** 3

**Prerequisites:** Senior Standing or instructor consent

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**BME 4972: Engineering in Medical Imaging I: Non-Ionizing Techniques**

(same as BIOL\_EN 4972; cross-leveled with BIOL\_EN 7972). This is the first course in a 2-semester investigation into the engineering of medical imaging modalities. These courses will provide the student with a functional understanding of some of the most common applications of engineering in medical imaging. This will include discussions of the underlying physics, device operation, image formation, and clinical applications of medical images including in-depth discussions on magnetic resonance imaging (MRI), ultrasound (US), and optical imaging. We will also examine the important topics of image resolution, signal-to-noise, image analysis, clinical decision-making in relation to diagnostic imaging, and emerging techniques in machine learning. This is an upper-level undergraduate/graduate course specifically targeted toward students with interest in careers in biomedical engineering, clinical technology, and medicine. Thus, a large portion of lecture will be dedicated to both theoretical development and applications in research and medicine.

**Credit Hours:** 3

**Prerequisites:** MATH 1500, PHYSCS 2750 and PHYSCS 2760 (or equivalents)

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**BME 4973: Engineering in Medical Imaging II: Ionizing Techniques**

(same as BIOL\_EN 4973; cross-leveled with BIOL\_EN 7973). This is the second course in a 2-semester investigation into the engineering of medical imaging modalities. These courses will provide the student with a functional understanding of some of the most common applications of engineering in medical imaging. This second course focuses on medical imaging techniques which involve ionizing energy sources and will include discussions of x-ray imaging (projection, mammography and CT), nuclear medicine (radiopharmaceuticals, scintigraphy, SPECT, and

PET), and radiation therapy. We will also examine the important topic of radiobiology and interactions of ionizing radiation with matter. This is an upper-level undergraduate/graduate course specifically targeted toward students with interest in careers in biomedical engineering, clinical technology, and medicine. Thus, a large portion of lecture will be dedicated to both theoretical development and applications in research and medicine.

**Credit Hours:** 3

**Prerequisites:** MATH 1400 or equivalent, BIOL\_EN 4972/BME 4972

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**BME 4980: Biomedical Engineering Design**

(same as BIOL\_EN 4980). Capstone design course for the biomedical engineering major. Design of biomedical devices or processes. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** ENGINR 1100 or MAE 1100, and ENGINR 2200, and BIOL\_EN 3180 or BME 3180, or instructor's consent

**Corequisites:** BIOL\_EN 4380 or BME 4380

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**BME 4980W: Biomedical Engineering Design - Writing Intensive**

(same as BIOL\_EN 4980W). Capstone design course for the biomedical engineering major. Design of biomedical devices or processes. Graded on A-F basis only.

**Credit Hours:** 3

**Prerequisites:** ENGINR 1100 or MAE 1100, and ENGINR 2200, and BIOL\_EN 3180 or BME 3180, or instructor's consent

**Corequisites:** BIOL\_EN 4380 or BME 4380

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**BME 4985: Bioengineering Design II**

(same as BIOL\_EN 4985). This course is intended to serve as the second term of our capstone, or senior design experience, for the Bachelor of Science in Biological Engineering or Biomedical Engineering degree programs. During this term, students will be expected to continue the design project begun by their team in the fall semester, carrying it through to prototyping, testing, and redesign. Students will continue their project under the advisement of the same faculty mentor and industrial cooperator who led their first term capstone experience. Graded on A-F basis only.

**Credit Hour:** 1-5

**Prerequisites:** BIOL\_EN 4980 or BME 4980. Instructor's consent required

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**BME 4990: Undergraduate Research in Biomedical Engineering**

Supervised independent study at the undergraduate level. Graded on A-F basis only.

**Credit Hour:** 1-6

**Prerequisites:** Department consent

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**BME 4995H: Undergraduate Honors Research in Biomedical Engineering**

(same as BIOL\_EN 4995H). Open only to honor students in Biological Engineering and Biomedical Engineering. Independent investigation in biological engineering to be presented as a thesis.

**Credit Hour:** 1-5

**Prerequisites:** Instructor consent, Honors eligibility required

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