

# BIOE - BIOENGINEERING

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## BIOE120 Biology for Engineers (3 Credits)

Introduction to the functions and interactions of biological systems from a quantitative perspective. Introduction to the modern experimental techniques and methods of data analysis. Roles for bioengineers in biology, and the role of biology in bioengineering will be elucidated.

**Prerequisite:** Must have completed or be concurrently enrolled in MATH140.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

## BIOE121 Biology for Engineers Laboratory (1 Credit)

Bioengineering encompasses numerous sub-disciplines that apply engineering principles to analyze biological systems and that utilize engineering design strategies to solve biological and biomedical problems. This course is aimed at providing students with the opportunity to learn how biology and engineering can synergistically contribute to our understanding of such problems, and to gain hands-on experience in basic techniques relevant to Bioengineering.

**Prerequisite:** Must have completed or be concurrently enrolled in BIOE120.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

## BIOE221 Academic and Career Planning (1 Credit)

Provides practical tools to help Bioengineering majors think critically about their goals and career paths. Guides Bioengineering students through accessing useful resources both on- and off-campus.

**Prerequisite:** Minimum grade of C- in BIOE120 and (BIOE121 or a minimum of 60 credits).

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

## BIOE232 Bioengineering Thermodynamics (3 Credits)

A quantitative introduction to thermodynamic analysis of bioengineering systems. Bioengineering encompasses a wide range of applications from nanoscale interactions (e.g. reactions between molecules), to cellular interactions (e.g. membrane electrical currents), to overall balances on organisms, all the way to large scale manufacturing. Each of these applications (and many others not mentioned) involve energy interactions which is the domain of thermodynamics. The basic laws of thermodynamics will be introduced and explained through a series of examples related to bioengineering systems.

**Prerequisite:** PHYS261 and PHYS260.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE232, ENES232, ENME232, or ENME320.

## BIOE241 Biocomputational Methods (3 Credits)

Introduction to programming and computational analysis in bioengineering using MATLAB. Emphasizes modeling of biological systems, biomedical data analysis, and engineering problem-solving. Includes an introduction to machine learning with applications such as biomedical signal classification and pattern recognition.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

## BIOE246 Differential Equations for Bioengineering (3 Credits)

Students will learn to solve differential equations, including linear first order differential equations, higher order differential equations, and partial differential equations. In addition, students will learn to apply differential equations to concepts in bioengineering.

**Prerequisite:** Minimum grade of C- in MATH243.

**Restriction:** Permission of the Fischell Department of Bioengineering.

## BIOE331 Biofluids (3 Credits)

Principles and applications of fluid mechanics with a focus on bioengineering topics. Content includes conservation of mass, momentum, and energy, as well as the application of these fundamental relations to hydrostatics, control volume analysis, internal and external flow, and boundary layers. Mass transfer via diffusion and convection is also introduced. Applications to biological and bioengineering problems such as tissue engineering, bioprocessing, imaging, and drug delivery.

**Prerequisite:** Minimum grade of C- in ENES102, BIOE120, BIOE241, and BIOE246; and must have completed with a minimum grade of C- or be concurrently enrolled in BIOE232.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**Credit Only Granted for:** BIOE331, ENCE305, ENFP300 or ENME331.

## BIOE332 Transport Process Design (3 Credits)

Fluid flow, heat transfer, and mass transfer with applications in medicine, environment, biotechnology, food, agriculture, and other biosystems. Design of solutions to current problems in biological engineering is emphasized.

**Prerequisite:** BIOE331.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

## BIOE340 Quantitative Physiology (4 Credits)

Human physiology from a systems perspective is integrated with quantitative methods to inform modeling approaches and bioengineering designs. A laboratory component is included.

**Prerequisite:** Minimum grade of C- in BSCI330 or (BSCI331 and BSCI332); and minimum grade of C- in BIOE331.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**Credit Only Granted for:** BIOE340, BSCI440, or BSCI450.

## BIOE371 Linear Systems and Ordinary Differential Equations for Bioengineering Applications (3 Credits)

This class utilizes fundamentals in linear systems, including eigenvalues and eigenvectors, as well as linear differential equations, to study various problems in bioengineering and biological systems, with a particular emphasis on feedback, stability, controllability, and control design.

**Prerequisite:** BIOE241; and must have completed or be concurrently enrolled in MATH246.

**Restriction:** Permission on ENGR-Fischell Department of Bioengineering department.

## BIOE372 Biostatistics for Experimental Design and Data Analysis (3 Credits)

This course will instruct students in the fundamentals of probability and statistics through examples in biological phenomenon, the design of bioengineering experiments, and clinical data analysis. Fundamentals covered in the course include probability distributions, hypothesis testing, power analysis, regression analysis, and correlation analysis.

**Prerequisite:** Minimum grade of C- in BIOE120 and BIOE241.

**Recommended:** MATH246.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**Credit Only Granted for:** BIOE372 or STAT464.

**BIOE386 Bioengineering Design and Teamwork (3 Credits)**

Focuses on the engineering design process, including needs finding, problem definition, inclusive design, and prototyping. Students will join an existing senior capstone design team and contribute to the project. This elective is designed to be taken directly prior to BIOE485, and will collaborate with the students and projects in that course. Students who complete BIOE386 may have the option to continue their capstone project in BIOE485.

**Prerequisite:** Minimum grade of C- in BIOE120 and BIOE241; and must have earned a minimum of 60 credits.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**BIOE389 Special Projects in Bioengineering (1-3 Credits)**

Exploring a variety of projects in Bioengineering.

**Restriction:** Permission of instructor; and permission of ENGR-Fischell Department of Bioengineering department.

**Repeatable to:** 6 credits.

**BIOE399 Independent Study in Bioengineering (1-3 Credits)**

Independent study.

**Prerequisite:** Permission of ENGR-Fischell Department of Bioengineering department.

**Repeatable to:** 12 credits if content differs.

**BIOE404 Biomechanics (3 Credits)**

Quantitative analysis of human movement using engineering mechanics and computational methods. Topics include kinematics, dynamics, inverse dynamics, joint biomechanics, anthropometry, and motion/force measurement, with hands-on labs and project-based learning focused on biomechanical modeling and analysis.

**Prerequisite:** Minimum grade of C- in ENES102, (MATH243 or MATH246), BIOE120, and BIOE241.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**BIOE411 Tissue Engineering (3 Credits)**

A review of the fundamental principles involved in the design of engineered tissues and organs. Both biological and engineering fundamentals will be considered.

**Prerequisite:** Minimum grade of C- in BIOE120 and either BSCI330 or (BSCI331 and BSCI332); and must have earned a minimum of 60 credits.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**BIOE413 Stem Cell Engineering (3 Credits)**

Provides an introduction to the role of stem cells in tissue growth and development, the engineering of stem cells and their environments for regenerative medicine applications, and disease modeling. Topics covered will include basic stem cell biology and mechanobiology; experimental methods for growing, differentiating, studying, and characterizing stem cells; stem cell integration into engineered microenvironments (e.g., tissue scaffolds and biomaterials, organ-on-chip devices, 3D-printed biomaterials); stem cell engineering in clinical applications and disease models; and ethical, commercialization, and regulatory issues in the field of stem cell engineering.

**Prerequisite:** Must have completed with a minimum grade of C- or be concurrently enrolled in BIOE340; and must have earned a minimum of 60 credits.

**Jointly offered with:** BIOE613.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**Credit Only Granted for:** BIOE413 or BIOE613.

**BIOE414 Macroscale Biomechanics (3 Credits)**

An overview of current problems in movement biomechanics. After taking this course, students will be able to 1) Describe the engineering tools needed to study human movement 2) Recognize a variety of clinical research and practice, and 3) Use the framework provided by the course to pursue their own self-teaching and research on these topics. Topics covered include muscle mechanics, joint mechanics, EMG and EEG signal applications, ultrasonography and elastography, anthropometry, human movement 3-D kinematics, inverse dynamics, forward dynamics, work, power and energy. Biomechanics tools will be used to investigate clinical problems. Students will also do research projects on related topics.

**Prerequisite:** Minimum grade of C- in BIOE120, BIOE241, ENES102, and (MATH243 or MATH246).

**Jointly offered with:** BIOE614.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE414 or BIOE614.

**BIOE415 Engineering Design for Global Health (3 Credits)**

Many medical technologies are not available in low and middle-income countries due to the cost, infrastructure, and medical expertise required to implement and sustain them. There is tremendous potential to increase access to health care through developing more affordable biomedical technologies, but effective design requires deep understanding of the problem. The goal of this course is to introduce the human-centered design framework and how it can be applied to design new biomedical technologies to solve challenges in global health.

**Prerequisite:** Minimum grade of C- in BIOE120; and must have earned a minimum of 60 credits.

**Jointly offered with:** BIOE615.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**Credit Only Granted for:** BIOE415, BIOE615, BIOE489Y, or BIOE689I.

**Formerly:** BIOE489Y.

**BIOE416 Cardiovascular Engineering (3 Credits)**

An overview of engineering applications in the cardiovascular system. Covers cardiovascular anatomy, physiology and pathophysiology in the context of cell and tissue mechanics, fluid mechanics, thermodynamics, biotransport, neurovascular coupling, and imaging. Includes design of cardiovascular devices, sensors, biomaterials, and tissue engineered constructs.

**Prerequisite:** Minimum grade of C- in BIOE340.

**Jointly offered with:** BIOE616.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**Credit Only Granted for:** BIOE416, BIOE616, BIOE489V, or BIOE689K.

**Formerly:** BIOE489V.

**BIOE420 Bioimaging (3 Credits)**

Covers the fundamental principles of major biomedical imaging techniques, including X-ray Imaging, Computer Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound Imaging, Nuclear Medicine Imaging (SPECT/PET/CT), Optical Coherent Tomography (OCT), and Optical and Hyperspectral Imaging. The course will explore the underlying concepts of imaging system architectures, image reconstruction algorithms, and software implementation. Additionally, it will discuss the clinical interpretation of biomedical images and newer ways to use images for bio-related applications for diagnosis and analysis.

**Prerequisite:** Minimum grade of C- in BIOE120, BIOE241, and BIOE246.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**BIOE431 Fundamentals of Biosensor Techniques, Instrumentation, and Applications (3 Credits)**

A thorough review of fundamental concepts of biosensing systems, principles of common detection methods, and modern applications of biosensors. Primarily literature driven. Students will obtain a detailed understanding of cutting-edge biosensing techniques, the instrumentation used, and the application space. Students also will develop skills in using current literature as a source of knowledge.

**Prerequisite:** Minimum grade of C- in BIOE120, CHEM135, and either BSCI330 or (BSCI331 and BSCI332).

**Jointly offered with:** BIOE631.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**Credit Only Granted for:** BIOE431, BIOE631, or BIOE658W.

**BIOE433 Optical Microscopy (3 Credits)**

Includes a large variety of techniques central in many fields of biological and engineering research as well as clinical medicine. This course will provide a comprehensive overview of the fundamentals of optical microscopy. At a fundamental level, the course will cover the interaction of light with tissue, cells and biomaterials, and the mathematical foundations that describe optical systems.

**Prerequisite:** Minimum grade of C- in BIOE120 and (MATH243 or MATH246).

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**BIOE437 Computer-Aided Design in Bioengineering (3 Credits)**

Introduction to Computer-Aided Design (CAD). Lecture topics will summarize design methodology, review best-practices in hardware development, and discuss engineering applications. The course will culminate in a student-selected project leveraging CAD.

**Prerequisite:** Minimum grade of C- in BIOE120 or must be in Engineering: Bioengineering program.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**Credit Only Granted for:** BIOE437, ENME414, or ENME272.

**BIOE442 Python: Introduction to Programming and Data Analysis (3 Credits)**

Provides an introduction to structured programming, computational methods, and data analysis techniques with the goal of building a foundation allowing students to confidently address problems in research and industry. Fundamentals of programming, algorithms, and simulation are covered from a general computer science perspective, while the applied data analysis and visualization portion makes use of the Python SciPy stack.

**Prerequisite:** Minimum grade of C- in BIOE120 and BIOE241.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**BIOE447 Clinical Experiences in Bioengineering (3 Credits)**

An immersion experience in the clinical settings in which biomedical engineering strategies, technologies, and practices are applied. An emphasis will be placed on both clinical problems and engineering solutions.

**Prerequisite:** Minimum grade of C- in BIOE120 and must have earned a minimum of 60 credits.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**BIOE453 Biomaterials (3 Credits)**

Examination of the structure and function of natural biomaterials, and cell-extracellular matrix interactions. Study physical properties of synthetic biomaterials for biomedical applications. Understanding molecular level interactions between biomolecules and biomaterials to design novel biomaterials with desirable characteristics. Application of biomaterials as implants, drug delivery systems, biosensors, engineered materials such as artificial skin and bone growth scaffolds will be covered.

**Prerequisite:** Minimum grade of C- in BIOE120 and CHEM231; must have earned a minimum of 60 credits.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**Credit Only Granted for:** BIOE453, CHBE457, or ENMA425.

**BIOE457 Biomedical Electronics & Instrumentation (4 Credits)**

Students learn fundamental concepts of electronics, assembly of electronic components into functional circuits, and integration of functional electronic devices and circuits into a system. In the lab component, students will learn to assemble and evaluate circuits and systems.

**Prerequisite:** Minimum grade of C- in BIOE120, BIOE241, BIOE246, PHYS260, and PHYS261.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department and must be in Engineering: Bioengineering program.

**BIOE461 Synthetic Biology and Biological Engineering (3 Credits)**

Students are introduced to the scientific foundation and concepts of synthetic biology and biological engineering. Current examples that apply synthetic biology to fundamental and practical challenges will be emphasized. The course will also address the societal issues of synthetic biology, and briefly examine interests to regulate research in this area.

**Prerequisite:** Minimum grade of C- in BIOE120, must have earned a minimum of 60 credits.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**BIOE462 Therapeutic Development and Delivery (3 Credits)**

The ultimate purpose of the pharmaceutical and biotechnology industries is the development and delivery of therapeutics. This course covers fundamentals of engineering and the pharmaceutical sciences related to therapeutics, including basic pharmaceuticals/drug delivery, pharmacokinetics, biomolecular kinetics, and regulatory issues. Specific focus is placed on biotherapeutics, including antibodies and protein engineering, RNA and DNA therapeutics (gene therapy and RNAi), extracellular vesicle biotechnology (exosomes), and cell-based therapies, including stem cells. The use of delivery technologies to enable therapeutics (e.g. nanomedicine) will also be discussed.

**Prerequisite:** Must have completed with a minimum grade of C- or be concurrently enrolled in BIOE340.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**BIOE464 Introduction to Computational Molecular Bioengineering (3 Credits)**

Designed to introduce students to the principles, methods, and software used for simulation and modeling of macromolecules of biological interest such as proteins, lipids, and polysaccharides. Along with experiment and theory, computational modeling provides new tools for analysis, explanation and prediction. The course is also useful for students who plan to use experimental techniques as their primary approach, but who will employ computational modeling as a tool to obtain integrative understanding of complex systems. Finally, the course should be valuable as an introductory overview for students planning to conduct their thesis research in computational modeling of biological systems. Class topics: Basic statistical thermodynamics, Force fields, Molecular dynamics/ monte carlo methods, Conformational analysis, Fluctuations & transport properties, Free-energy calculations, Multiscale modeling.

**Prerequisite:** Minimum grade of C- in BIOE232, BIOE372, and BIOE442; and minimum grade of C- in BIOE371 or BIOE246; or permission of Fischell Department of Bioengineering.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**BIOE468 Selected Topics in Bioengineering (3 Credits)**

Selected topics in Bioengineering will be covered and taught by a variety of department faculty.

**Prerequisite:** BIOE120 and BIOE121.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Repeatable to:** 9 credits if content differs.

**BIOE474 Biopharmaceutical Process Development and Manufacturing (3 Credits)**

Covers the fundamental steps involved in process development and manufacturing of biopharmaceuticals. An overview of different classes of biopharmaceuticals as well as manufacturing requirements for clinical development and regulatory approval will be provided. In depth coverage of manufacturing steps including cell culture, purification and formulation as well as drug product manufacturing, analysis and stability will be covered. Scientific literature will be used to highlight current challenges and novel solutions in each step of the manufacturing process. Scale up considerations, GMP requirements and process economics will also be introduced.

**Prerequisite:** Minimum grade of C- in BIOE120 and must have earned a minimum of 60 credits.

**Jointly offered with:** BIOE674.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering and must be in Engineering: Bioengineering program.

**Credit Only Granted for:** BIOE474, BIOE674, CHBE474, BIOE489T, or BIOE689E.

**Formerly:** BIOE489T.

**BIOE485 Capstone Design I: Entrepreneurship, Regulatory Issues, and Ethics (3 Credits)**

This is the first part of a two-semester senior capstone design course which covers principles involved in engineering design, design approaches, economics of design, ethics in engineering, and patent regulations. It also helps students learn team work and write design project proposals under the mentorship of a faculty advisor.

**Prerequisite:** 21 credits in BIOE courses; and must have completed or be concurrently enrolled in BIOE457.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department; and senior standing; and must be in Engineering: Bioengineering program.

**BIOE486 Capstone Design II (3 Credits)**

This is the second part of the senior capstone design course. This part is independent instruction where faculty mentoring each project team works with students to order supplies, fabricate their proposed design under BIOE485, test the design, write the report and present it to their fellow seniors and board of faculty mentors. Students are taught to convert the blue print of a design to actual device and test it.

**Prerequisite:** Must have completed BIOE485 in the immediately preceding semester.

**Restriction:** Senior standing; and must be in Engineering: Bioengineering program; and permission of ENGR-Fischell Department of Bioengineering department.

**Credit Only Granted for:** BIOE486 or ENBE486.

**Formerly:** ENBE486.

**BIOE488 Research Methods in Bioengineering (1-3 Credits)**

Exploring a variety of research methods in the field of Bioengineering.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Repeatable to:** 9 credits if content differs.

**BIOE489 Special Topics in Bioengineering (1-3 Credits)**

Exploring a variety of topics with Bioengineering.

**Restriction:** Permission of ENGR-Fischell Department of Bioengineering department.

**Repeatable to:** 6 credits.