Biological Engineering

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Biological Engineering is a science-based engineering curriculum that filters the critical engineering concepts of mathematical modeling, process control, and materials science through the lens of biology and living things. From a single biomolecule or cell, to a whole tissue or organism, to a whole ecosystem, biological engineering integrates engineering science and design with biological and related sciences to provide novel solutions in the areas of health, sustainability and environmental stewardship. Students are prepared through courses in mathematics, biological sciences, and physical sciences; core biological engineering principles; and then one of three biological engineering track areas: biomedical, bioprocess, or bioenvironmental engineering. Graduates are hired by biotechnology, medical, pharmaceutical, food and agricultural companies and government agencies, or opt to further their education in graduate, medical or veterinary medical school.

Faculty

Primary Faculty

Professors S. Ding**, K. D. Gillis**, S. A. Grant**, L. Gu**, R. Kannan**, X. Liu**, J. Tan**, G. Yao**
Associate Professors D. Gil Pages*, A. Schrum**, S. Sengupta**, R. Thomen**, C. Wan**, Z. Yan**
Assistant Professors N. Aloysius**, K. Krishnaswamy**, P. Somavat**, C. Sun**
Assistant Teaching Professors M. Collins, C. Darr*
Professor Emeritus S. C. Borgelt**,** F. H. Hsieh, A. L. Thompson**

Affiliated Faculty

Professors D. Burke**, P. Carney**, D. Duan*, K. V. Katti*, S. Lombardo*, S. Nair**, S. Segal*, P. Yu*, Q. Yu**, R. N. Zia*
Associate Professors T. M. Guess**, T. T. Lim**, J. Lin**, M. Maschmann*, L. Polo-Parada**, J. Zhou**
Assistant Professors J. Zulovich*
Adjunct Professors J. Ghosh, G. Guidoboni**, K. A. Sudduth**, E. Vories

* Graduate Faculty Member - membership is required to teach graduate-level courses, chair master's thesis committees, and serve on doctoral examination and dissertation committees.
** Doctoral Faculty Member - membership is required to chair doctoral examination or dissertation committees. Graduate faculty membership is a prerequisite for Doctoral faculty membership.

Undergraduate

- BSBE in Biological Engineering (https://catalog.missouri.edu/collegeofengineering/biologicalengineering/bsbe-biological-engineering/)

Advising and Scholarship Contacts
Charles Darr, Director of Undergraduate Studies
W2029 Lafferre Hall
(573) 882-7044
darrcm@missouri.edu

Engineering Advising Office
Phone: 573-884-6961
Email: muengradvising@missouri.edu
Website: https://engineering.missouri.edu/student-services/advising/

Biological engineering is a science-based engineering discipline that integrates engineering and biological sciences in one curriculum. The MU biological engineering program is a broadly-based curriculum that prepares students for careers in three areas:

- Biomedical engineering (including pre-medicine)
- Bioprocess engineering
- Bioenvironmental engineering

Biological engineering graduates are hired by biotechnology, medical, pharmaceutical, food and agricultural companies, and by government agencies. Some attend graduate and medical schools. Graduates are well prepared to take the Fundamentals of Engineering exam during their senior year, which is the first step toward obtaining a Professional Engineer license.

The biological engineering curriculum was developed to meet the mission, program objectives and student outcomes described below.

Mission and Objectives

The department mission is to educate biological engineers to integrate engineering and biological sciences in the contexts of health, sustainability and environmental stewardship, thus preparing them for productive careers characterized by continual professional growth.

Program Educational Objectives:

The undergraduate programs lead to a BS BE, producing graduates who, within a few years of graduation, will be prepared to:

- meet the expectations of employers of biological engineers.
- pursue advanced study and/or continuing education if desired.
- pursue leadership positions in their profession and/or communities.

Student Outcomes:

Students from the BS BE program will attain by the time of graduation:

1. An ability to identify, formulate, and solve engineering programs by applying principles of engineering, science, and mathematics
2. An ability to apply both analysis and synthesis in the engineering design process, resulting in designs that meet desired needs
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Graduate

- MS in Biological Engineering (https://catalog.missouri.edu/collegeofengineering/biologicalengineering/ms-biological-engineering/)
- PhD in Biological Engineering (https://catalog.missouri.edu/collegeofengineering/biologicalengineering/phd-biological-engineering/)

Admissions and Advising Contacts:
Department of Chemical & Biomedical Engineering
Reginald E Rogers, Jr. (rerogers@missouri.edu), Director of Graduate Studies
W2024 Lafferre Hall
(573) 882-4103
https://engineering.missouri.edu/departments/chbme/

About Biological Engineering

Biological engineering (BE) is a science-based engineering discipline that integrates engineering with biological sciences in one curriculum. Bioengineers apply scientific and engineering principles of design and analysis to develop products, systems, and/or processes for improving human and animal health, bio-resource utilization, and environment protection.

The BE Graduate Program awards traditional PhD (https://engineering.missouri.edu/degree/phd-in-biological-engineering/) and MS (https://engineering.missouri.edu/degree/master-of-science-in-biological-engineering/) as well as a 100% online, non-thesis MS (https://online.missouri.edu/degrees-programs/mu/engineering/biological-engineering/ms/) degrees in Biological Engineering with three emphasis areas: biomedical engineering, bioprocess engineering, and bioenvironmental engineering. We also administer the Master of Engineering (ME (https://engineering.missouri.edu/degree/master-of-engineering/)) degree offered by the College of Engineering with a focus in Biological Engineering.

Faculty Research

BE graduate faculty members conduct interdisciplinary research and have close collaborations with other faculty across the campus. Such a diverse yet synergetic faculty body is unique at University of Missouri and provides an excellent environment to educate and train the next generation engineers and scientists with knowledge and skills crossing traditional boundaries.

Facilities and Resources

BE faculty members maintain state-of-the-art laboratory facilities in their research areas. Laboratories are well equipped for research in biomaterials, biomechanics, biophotonics & imaging, biosensors, electrophysiology, nanoengineering, neural engineering, bioprocessing, environmental engineering, hydrology and renewable energy, precision agriculture, properties of biological and food materials, soil physics. The department has access to the University of Missouri System computing network and maintains its own computing laboratory for student use.

Financial Aid

Admission decisions to the BE graduate programs are made independent of a student's financial need. Once admitted, a qualified student will be considered for funding support in forms of fellowships, graduate research assistantships (GRAs), and graduate teaching assistantships (GTAs). Nominations for college- and campus-wide fellowship competitions are initiated by the department. GRAs and GTAs are awarded by individual faculty members or course instructors upon approval from the department. Applicants who are interested in funding support should submit the graduate admission application by the "priority" deadlines as indicated on the graduate admission page (https://gradschool.missouri.edu/degreecategory/bioengineering/).

BIOL_EN 1000: Introduction to Biological Engineering
For first semester engineering students. Develop appreciation for professional engineering. Students will participate with senior design students to conceptualize a case-study problem.

Credit Hour: 1-2

BIOL_EN 2000: Professional Development in Engineering
(same as BME 2000). A review of professional opportunities, registration, ethics, and societies. Graded on A-F basis only.

Credit Hours: 2
Prerequisites: sophomore standing

BIOL_EN 2001: Topics in Biological Engineering
Current and new technical developments in biological engineering. Graded on A-F basis only.

Credit Hour: 1-5

BIOL_EN 2017: World of Neuroscience
(same as BIO_SC 2017, PSYCH 2017, BME 2017, CMP_SC 2017, ECE 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 only.

Credit Hour: 1

BIOL_EN 2070: Cell and Molecular Biology for Engineers
(same as BME 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 or CHEM 1400 and CHEM 1401, and MATH 1500

BIOL_EN 2080: Introduction to Programming for Engineers
(same as BME 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

BIOL_EN 2180: Engineering Analysis of Bioprocesses
(same as BME 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 1400 and CHEM 1401, PHYSCS 2750
Recommended: BIOL_EN 2080

BIOL_EN 2600: Sustainability Foundations: An Introduction to Sustainability
(same as ENV_SC 2600). This course introduces fundamental concepts of sustainability from sustainable development to sustainability science. It focuses on human-environment systems, the characteristics of these systems, and patterns of change. Course materials interrogate taken-for-granted assumptions that shape human relationships with the natural world. You will learn to identify common dynamics leading to social and environmental problems with the aim of identifying alternative actions (solutions) for transitioning towards sustainability. Sustainability integrates the social and biophysical sciences; and implementing solutions requires the integration of the social justice, the arts, and humanities. Through a variety of interdisciplinary perspectives and frameworks, you will learn about current sustainability research and be able to develop an understanding of what sustainability means to you and your field of study. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: sophomore standing

BIOL_EN 2600H: Sustainability Foundations: An Introduction to Sustainability - Honors
(same as ENV_SC 2600H). This course introduces fundamental concepts of sustainability from sustainable development to sustainability science. It focuses on human-environment systems, the characteristics of these systems, and patterns of change. Course materials interrogate taken-for-granted assumptions that shape human relationships with the natural world. You will learn to identify common dynamics leading to social and environmental problems with the aim of identifying alternative actions (solutions) for transitioning towards sustainability. Sustainability integrates the social and biophysical sciences; and implementing solutions requires the integration of the social justice, the arts, and humanities. Through a variety of interdisciplinary perspectives and frameworks, you will learn about current sustainability research and be able to develop an understanding of what sustainability means to you and your field of study. Graded on A-F basis only. Honors eligibility required

Credit Hours: 3
Prerequisites: sophomore standing

BIOL_EN 3070: Biological Fluid Mechanics
(same as BME 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

BIOL_EN 3075: Introduction to Materials Engineering
(same as BME 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

BIOL_EN 3170: Biomaterials
(same as BME 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.

Credit Hours: 3
Prerequisites: BIOL_EN 3075 or BME 3075
Corequisites: BIOL_EN 2180, ENGINR 2200 or instructor's consent

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BIOL_EN 3170W: Biomaterials - Writing Intensive
(same as BME 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.

Credit Hours: 3
Prerequisites: BIOL_EN 3075 or BME 3075
Corequisites: BIOL_EN 2180, ENGINR 2200 or instructor's consent

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BIOL_EN 3180: Heat and Mass Transfer in Biological Systems
(same as BME 3180). Principles of heat and mass transfer and their applications in biomedical, bioenvironmental, and bioprocessing engineering.

Credit Hours: 3
Prerequisites or Corequisites: ENGINR 2300 or CH_ENG 3261
Prerequisites: BIOL_EN 2180 or CH_ENG 2225

BIOL_EN 3330: Fermentation for Food, Fuel and Beverages
(same as F_S 3330). Covers the underlying principles of fermentation and their applications as utilized to produce fermented food, fuel and alcoholic beverages. Discussion of microorganisms, their metabolism and physiology. Unit operations involved in manufacture of fermented dairy, vegetable, and meat products; biofuel production from corn; production of beer, wines and distilled spirits; introduction to biorefineries. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: MATH 1100 and CHEM 1400 and CHEM 1401

BIOL_EN 4001: Topics in Biological Engineering
Current and new technical developments in biological engineering.

Credit Hour: 3-9

BIOL_EN 4001H: Topics in Biological Engineering - Honors
Current and new technical developments in biological engineering.

Credit Hour: 3-9
Prerequisites: Honors eligibility required

BIOL_EN 4050: Zero Hunger Challenge
(same as F_S 4050; cross-leveled with F_S 7050, BIOL_EN 7050). Students from multidisciplinary background are formed into teams to address food and nutrition security. Students will learn about Sustainable Development Goal (SDG) 2: Zero Hunger, importance of partnership for the goals (SDG-17) to address grand global challenges. Transdisciplinary student teams will develop a proposal at the end of the course and are encouraged to participate in challenge competitions.

Credit Hours: 3

BIOL_EN 4050H: Zero Hunger Challenge - Honors
(same as F_S 4050H; cross-leveled with F_S 7050, BIOL_EN 7050). Students from multidisciplinary background are formed into teams to address food and nutrition security. Students will learn about Sustainable Development Goal (SDG) 2: Zero Hunger, importance of partnership for the goals (SDG-17) to address grand global challenges. Transdisciplinary student teams will develop a proposal at the end of the course and are encouraged to participate in challenge competitions.

Credit Hours: 3
Prerequisites: Honors eligibility required

BIOL_EN 4070: Bioelectricity
(cross-leveled with BIOL_EN 7070). Application of engineering approaches to understand bioelectricity at the cellular level including the equivalent circuit of cell membranes and the electronic design of patch-clamp amplifiers.

Credit Hours: 3
Prerequisites: PHYSCS 2760 and BIOL_EN 3180

BIOL_EN 4075: Brain Signals and Brain Machine Interfaces
(same as BME 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

BIOL_EN 4085: Problems in Biological Engineering
Supervised independent study at the undergraduate level.

Credit Hour: 1-5
Prerequisites: instructor's consent

BIOL_EN 4150: Soil and Water Conservation Engineering
(same as CV_ENG 4710; cross-leveled with BIOL_EN 7150, CV_ENG 7710). Urban and rural run-off and erosion analysis. Design and layout of erosion control structures.

Credit Hours: 3
Recommended: BIOL_EN 2180 or CV_ENG 3200

BIOL_EN 4160: Food Process Engineering
(same as F_S 4160, CH_ENG 4160; cross-leveled with CH_ENG 7160, BIOL_EN 7160, F_S 7160). Food engineering is an interdisciplinary field that connects agricultural and biological engineering, chemical engineering, food science, biochemistry, human nutrition, and other fields involving food systems to improve the health of people and planet. The course introduces underlying engineering principles in food processing, and unit operations in food industries. Topics include fluid flow, heat transfer in food processing, preservation process, dehydration, refrigeration, food freezing, psychrometrics, food packaging, emerging technologies, and sustainability.

Credit Hours: 3
Prerequisites: BIOL_EN 3180, BME 3180, or consent of instructor

BIOL_EN 4170: Biomaterials Interfaces of Implantable Devices
(same as BME 4170; cross-leveled with BIOL_EN 7170). Surface structures and properties to improve biocompatibility will be studied. Engineering sciences and design will be leverage in the design of an improved biocompatible surface.

Credit Hours: 3
Prerequisites: BIOL_EN 3170

BIOL_EN 4175: Tissue Engineering
(same as BME 4175; cross-leveled with BIOL_EN 7175). The course encompasses the application of engineering principles combined with cell biology, medicine, and materials science to understand tissue engineering and regenerative medicine. It provides a fundamental understanding of property-function relationships in biomaterials and cells during tissue growth and development required to restore or improve tissue and organ functions as well as to design tissue-engineered constructs. Graded on A-F basis only. Prerequisites: CHEM 2100 and one the following: BME 3075, or BME 3170, or ENGINR 2200.

Credit Hours: 3

BIOL_EN 4231: Transport Phenomena in Materials Processing
(same as MAE 4231, CH_ENG 4231; cross-leveled with BIOL_EN 7231, MAE 7231, CH_ENG 7231). Applications of fluid flow, heat transfer, and mass transfer in steady-state and unsteady-state materials processing with applications to metals, polymers, and ceramics. Graded on A-F basis only.

Credit Hours: 3
Prerequisites or Corequisites: BIOL_EN 3180 or BME 3180
Prerequisites: C- or better in MATH 4100

BIOL_EN 4250: Irrigation and Drainage Engineering
(same as CV_ENG 4740; cross-leveled with BIOL_EN 7250, CV_ENG 7740). Soil, water, plant relationships. Water supplies and design of surface, sprinkler and drip irrigation systems. Surface and tile drainage.

Credit Hours: 3
Prerequisites: CV_ENG 3700 or MAE 3400 or BIOL_EN 2180

BIOL_EN 4270: Design of Experiments and Statistical Quality Control for Process Engineers
(same as CH_ENG 4270; cross-leveled with BIOL_EN 7270, CH_ENG 7270). A practical statistical tool box for experimenters including comparison of process means, effects of variables, design and interpretation of factorial experiments, and statistical quality control.

Credit Hours: 3
Recommended: experience with Excel or instructor's consent

BIOL_EN 4310: Feedback Control Systems
(same as ECE 4310, MAE 4750, CMP_SC 4315; cross-leveled with BIOL_EN 7310, ECE 7310, MAE 7750, CMP_SC 7315). System modeling and time and frequency response, closed loop control, stability, continuous system design, introduction to descrete time control, software and hardware experiments on compensator design and PID control. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: MATH 4100 and junior/senior standing

BIOL_EN 4315: Principles of Biochemical Engineering
(same as CH_ENG 4315; cross-leveled with BIOL_EN 7315, CH_ENG 7315). This course serves as an introduction to the application of biological, biochemical, and engineering fundamentals for biochemical processing. Topics include biological basics, enzyme kinetics, metabolic pathways, cell growth kinetics, analysis of intracellular flux, thermodynamics of biological reactions, and bioreactor design and modeling. Analyses proceed through the use of mass balances, energy balances, and empirical or theoretical models.

Credit Hours: 3
Prerequisites: BIOL_EN 2180 (for Biological Engineering students) or CH_ENG 2225 (for Chemical Engineering students) or Instructor's consent
Recommended: BIOL_EN 3180 (for Biological Engineering students) or CH_ENG 3234 (for Chemical Engineering students) as a prerequisite or a co-requisite

BIOL_EN 4316: Biomass Refinery Operations
(same as CH_ENG 4316; cross-leveled with BIOL_EN 7316, CH_ENG 7316). Design and operation of processes for conversion and/or fractionation of biomass and associated upstream and downstream unit operations. Emphasis on separations and product recovery.

Credit Hours: 3
Recommended: BIOL_EN 2180 or CH_ENG 2225 (for Chemical Engineering students) or instructor's consent

BIOL_EN 4350: Watershed Modeling Using GIS
(same as CV_ENG 4720; cross-leveled with BIOL_EN 7350, CV_ENG 7720). Watershed evaluation using AVSWAT for hydrology, sediment yield, water quality; includes USLE, MUSLE, WEPP. Procedures for model calibration/sensitivity data analysis.

Credit Hours: 3
Recommended: BIOL_EN 2180 or CV_ENG 3200 or instructor's consent

BIOL_EN 4360: Biomanufacturing Technologies
(same as BME 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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BIOL_EN 4370: Orthopaedic Biomechanics
(same as BME 4370, MAE 4211; cross-leveled with BIOL_EN 7370, MAE 7211). Engineering sciences will be leverage 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

BIOL_EN 4375: Human Movement Biomechanics
(same as BME 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

BIOL_EN 4380: Applied Electronic Instrumentation
(same as BME 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

BIOL_EN 4420: Introduction to Biomedical Imaging
(same as BME 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

BIOL_EN 4450: Environmental Hydrology
(same as ENV_SC 4450; cross-leveled with BIOL_EN 7450, ENV_SC 7450). This course provides an understanding, and the roles of natural processes and anthropogenic factors influencing the occurrence and the movement of water. Students will learn the quantitative basis of hydrology, which will help them to appreciate the scientific approach to understanding the observed phenomena. The material presented will provide sufficient knowledge for students to evaluate hydrologic processes associated with environmental systems and to develop conceptual evaluations that are part of water and natural resource assessments. Learning objectives: 1. Describe basic mechanisms and variables of hydrologic fluxes and states 2. Describe and define different mathematical formulations of hydrologic fluxes and states 3. Understand key components of a watershed model 4. Analyze, synthesize and interpret hydrologic data.

Credit Hours: 3
Prerequisites: MATH 1100 or MATH 1400 or STAT 1300 or consent of the instructor

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BIOL_EN 4470: Biomolecular Engineering and Nanobiotechnology
(same as BME 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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BIOL_EN 4470H: Biomolecular Engineering and Nanobiotechnology - Honors
(same as BME 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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BIOL_EN 4480: Physics and Chemistry of Materials
(same as PHYSCS 4190,CHEM 4490, NU_ENG 4319, BME 4480; 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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BIOL_EN 4540: Neural Models and Machine Learning
(same as BME 4540, CMP_SC 4540, ECE 4540; cross-leveled with CMP_SC 7540, ECE 7540, BIOL_EN 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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BIOL_EN 4560: Observing the Earth from Space
(same as ENV_SC 4560; cross-leveled with ENV_SC 7560, BIOL_EN 7560). This course provides an understanding of the theory and application of earth observing satellite remote sensing as a tool for environmental engineering and science. The topics include the fundamentals of electromagnetic radiation, satellite and sensor technology, integration of satellite and GIS data and digital image analysis. The lectures and homework assignments at the beginning of the course provide the necessary foundation to work with satellite imagery. Students will receive training with advanced image processing software and data acquisition techniques. The course will also cover case studies using remote sensing and image analysis techniques to answer real-world problems. The lectures and homework assignments include applications in forest management, land use change detection, monitoring agricultural activities, water and air quality monitoring, climate studies, and ecology and infectious diseases. The course will cover lectures on advanced remote sensing techniques towards the end of the course. Students will work on their independent projects during the last three weeks, applying remote sensing techniques to satellite images.

Credit Hours: 3
Prerequisites: MATH 1100 or MATH 1400 or STAT 1300 or consent of the instructor

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BIOL_EN 4570: Fluorescent Imaging
(same as BME 4570; cross-leveled with BIOL_EN 7570). Principles and applications of fluorescent imaging. The course covers: Image formation in microscope; Fundamentals of fluorescence and fluorescent microscopy; molecular and cellular fluorescent imaging.

Credit Hours: 3
Prerequisites: BIO_SC 1500 and BIOL_EN 2180 or instructor's consent

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BIOL_EN 4590: Computational Neuroscience
(same as BIO_SC 4590, ECE 4590, BME 4590, CMP_SC 4590, PSYCH 4591; cross-leveled with BIOL_EN 7590, BIO_SC 7590, ECE 7590, CMP_SC 7590, PSYCH 7591). 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

BIOL_EN 4770: Biomedical Optics
(same as BME 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

BIOL_EN 4940: Engineering Internship
(same as BME 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

BIOL_EN 4970: Nuclear Magnetic Resonance and Magnetic Resonance Imaging
(same as BME 4970; cross-leveled with BIOL_EN 7970). 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. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: Senior Standing or Instructor Consent

BIOL_EN 4972: Engineering in Medical Imaging I: Non-Ionizing Techniques
(same as BME 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 PHYSICS 2760 (or equivalents)

BIOL_EN 4973: Engineering in Medical Imaging II: Ionizing Techniques
(same as BME 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

BIOL_EN 4974: Medical Image Processing
(same as BME 4974; cross-leveled with BIOL_EN 7974). This course is designed to provide an exploration into medical image processing, encompassing a comprehensive understanding of foundational principles and algorithms inherent to medical imaging. This will include fundamental concepts in medical images, image enhancement, image segmentation and image registration. We will also dig into MRI modality, emphasizing critical components like Fourier Transform, Motion Correction, the integration of Artificial Intelligence within MRI Image Processing, Clinical Applications and Case Studies. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: MATH 1500
Recommended: BME 2080, ECE 4655

BIOL_EN 4980: Bioengineering Design I
(same as BME 4980). Capstone design course for Biological Engineering or Biomedical Engineering major. Design of devices or processes for biological or biomedical applications.

Credit Hours: 3
Prerequisites: ENGINR 1100 or MAE 1100, ENGINR 2200, and BIOL_EN 3180 or BME 3180, or instructor's consent
Corequisites: BIOL_EN 4380 or BME 4380

BIOL_EN 4980W: Bioengineering Design I - Writing Intensive
(same as BME 4980W). Capstone design course for Biological Engineering or Biomedical Engineering major. Design of devices or processes for biological or biomedical applications.

Credit Hours: 3
Prerequisites: ENGINR 1100 or MAE 1100, ENGINR 2200, and BIOL_EN 3180 or BME 3180, or instructor's consent
Corequisites: BIOL_EN 4380 or BME 4380

BIOL_EN 4985: Bioengineering Design II
(same as BME 4985). Second term of capstone, senior design course for the Biomedical Engineering major. Design of biological system devices or processes. Includes prototyping and testing of design. Graded on A-F basis only.

Credit Hour: 1-3
Prerequisites: BIOL_EN 4980 or BME 4980. Instructor's consent required

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BIOL_EN 4990: Undergraduate Research in Biological Engineering
Supervised independent study at the undergraduate level.

Credit Hour: 1-5
Prerequisites: instructor's consent

BIOL_EN 4995: Undergraduate Honors Research in Biological Engineering
Open only to honor students in Biological Engineering. Independent investigation in biological engineering to be presented as a thesis.

Credit Hour: 1-5
Prerequisites: advisor's consent

BIOL_EN 4995H: Undergraduate Honors Research in Biological Engineering
(same as BME 4995H). Open only to honor students in Biological Engineering. Independent investigation in biological engineering to be presented as a thesis.

Credit Hour: 1-5
Prerequisites: advisor's consent. Honors eligibility required

BIOL_EN 7001: Topics in Biological Engineering
Study of advanced developments in biological engineering.

Credit Hour: 1-3

BIOL_EN 7050: Zero Hunger Challenge
(same as F_S 7050; cross-leveled with BIOL_EN 4050, F_S 4050). Students from multidisciplinary background are formed into teams to address food and nutrition security. Students will learn about Sustainable Development Goal (SDG) 2: Zero Hunger, importance of partnership for the goals (SDG-17) to address grand global challenges. Transdisciplinary student teams will develop a proposal at the end of the course and are encouraged to participate in challenge competitions.

Credit Hours: 3

BIOL_EN 7070: Bioelectricity
(cross-leveled with BIOL_EN 4070). Application of engineering approaches to understand bioelectricity at the cellular level including the equivalent circuit of cell membranes and the electronic design of patch-clamp amplifiers. Prerequisites: PHYSCS 2760 and BIOL_EN 3180 or instructor's consent

Credit Hours: 3

BIOL_EN 7075: Brain Signals and Brain Machine Interfaces
(cross-leveled with BIOL_EN 4075, BME 4075). 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

BIOL_EN 7150: Soil and Water Conservation Engineering
(same as CV_ENG 7710; cross-leveled with BIOL_EN 4150, CV_ENG 4150). Urban and rural run-off and erosion analysis. Design and layout of erosion control structures.

Credit Hours: 3
Prerequisites: BIOL_EN 2180 or CV_ENG 3200, or instructor's consent

BIOL_EN 7160: Food Process Engineering
(same as F_S 7160, CH_ENG 7160; cross-leveled with BIOL_EN 4160, F_S 4160, CH_ENG 4160). Food engineering is an interdisciplinary field that connects agricultural and biological engineering, chemical engineering, food science, biochemistry, human nutrition, and other fields involving food systems to improve the health of people and planet. The course introduces underlying engineering principles in food processing, and unit operations in food industries. Topics include fluid flow, heat transfer in food processing, preservation process, dehydration, refrigeration, food freezing, psychrometrics, food packaging, emerging technologies, and sustainability.

Credit Hours: 3
Prerequisites: BIOL_EN 3180, BME 3180 or instructor's consent

BIOL_EN 7170: Biomaterials Interfaces of Implantable Devices
(cross-leveled with BIOL_EN 4170, BME 4170). Surface structures and properties to improve biocompatibility will be studied. Engineering sciences and design will be leverage in the design of an improved biocompatible surface.

Credit Hours: 3
Prerequisites: BIOL_EN 3170 or instructor's consent

BIOL_EN 7175: Tissue Engineering
(cross-leveled with BIOL_EN 4175, BME 4175). The course encompasses the application of engineering principles combined with cell biology, medicine, and materials science to understand tissue engineering and regenerative medicine. It provides a fundamental understanding of property-function relationships in biomaterials and cells during tissue growth and development required to restore or improve tissue and organ functions as well as to design tissue-engineered constructs. Graded on A-F basis only. Prerequisites: CHEM 2100 and one the following: BME 3075, or BME 3170, or ENGINR 2200.

Credit Hours: 3

BIOL_EN 7231: Transport Phenomena in Materials Processing
(same as MAE 7231, CH_ENG 7231; cross-leveled with BIOL_EN 4231, MAE 4231, CH_ENG 4231). Applications of fluid flow, heat transfer, and mass transfer in steady-state and unsteady-state materials processing with applications to metals, polymers, and ceramics. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: MATH 4100, BIOL_EN 3070, BIOL_EN 3075, and BIOL_EN 3180 or equivalents

BIOL_EN 7250: Irrigation and Drainage Engineering
(same as CV_ENG 7740; cross-leveled with BIOL_EN 4250, CV_ENG 4740). Soil, water, plant relationships. Water supplies and design of surface, sprinkler and drip irrigation systems. Surface and tile drainage.

Credit Hours: 3
Prerequisites: CV_ENG 3700 or MAE 3400 or BIOL_EN 2180

BIOL_EN 7310: Feedback Control Systems
(same as ECE 7310, MAE 7750, CMP_SC 7315; cross-leveled with ECE 4310, BIOL_EN 4310, MAE 4750, CMP_SC 4315). System modeling and time and frequency response, closed loop control, stability, continuous system design, introduction to descrete time control, software and hardware experiments on compensator design and PID control. Graded A-F only. May be repeated for credit.

Credit Hours: 3
Prerequisites: MATH 4100

BIOL_EN 7315: Introduction to Bioprocess Engineering
(same as CH_ENG 7315; cross-leveled with BIOL_EN 4315, CH_ENG 4315). This course serves as an introduction to the application of biological, biochemical, and engineering fundamentals for biochemical processing. Topics include biological basics, enzyme kinetics, metabolic pathways, cell growth kinetics, analysis of intracellular flux, thermodynamics of biological reactions, and bioreactor design and modeling. Analyses proceed through the use of mass balances, energy balances, and empirical or theoretical models.

Credit Hours: 3
Prerequisites: BIOL_EN 2180 (for Biological Engineering students) or CH_ENG 2225 (for Chemical Engineering students) or Instructor's consent
Recommended: BIOL_EN 3180 (for Biological Engineering students) or CH_ENG 3234 (for Chemical Engineering students) as a prerequisite or a co-requisite

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BIOL_EN 7316: Biomass Refinery Operation
(same as CH_ENG 7316; cross-leveled with BIOL_EN 4316, CH_ENG 4316). Design and operation of processes for conversion and/or fractionation of biomass and associated upstream and downstream unit operations. Emphasis on separations and product recovery.

Credit Hours: 3
Prerequisites: BIOL_EN 2180 or CH_ENG 2225 or instructor's consent

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BIOL_EN 7350: Watershed Modeling Using GIS
(same as CV_ENG 7720; cross-leveled with BIOL_EN 4350, CV_ENG 4720). Watershed evaluation using AVSWAT for hydrology, sediment yield, water quality; includes USLE, MUSLE, WEPP, Procedures for model calibration/sensitivity data analysis.

Credit Hours: 3
Prerequisites: BIOL_EN 2180 or CV_ENG 3200 or instructor's consent

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BIOL_EN 7360: Biomanufacturing Technologies
(same as CH_ENG 7360; cross-leveled with BIOL_EN 4360, CH_ENG 4360). This course is an introduction to biomanufacturing technologies and processes for manufacturing biological products (e.g., vaccines, 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 or equivalents

BIOL_EN 7370: Orthopaedic Biomechanics
(same as MAE 7211; cross-leveled with BIOL_EN 4370, BME 4370, MAE 4211). Engineering sciences will be leverage 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

BIOL_EN 7375: Human Movement Biomechanics
(cross-leveled with BIOL_EN 4375, BME 4375). 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

BIOL_EN 7380: Applied Electronic Instrumentation
(cross-leveled with BIOL_EN 4380, BME 4380). 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

BIOL_EN 7420: Introduction to Biomedical Imaging
(same as PHYSCS 7420; cross-leveled with BIOL_EN 4420, BME 4420, PHYSCS 4420). 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, as well as recent developments in biomedical imaging.

Credit Hours: 3
Prerequisites: PHYSCS 2760

BIOL_EN 7450: Environmental Hydrology
(same as ENV_SC 7450; cross-leveled with ENV_SC 4450, BIOL_EN 4450). This course provides an understanding, and the roles of natural processes and anthropogenic factors influencing the occurrence and the movement of water. Students will learn the quantitative basis of hydrology, which will help them to appreciate the scientific approach to understanding the observed phenomena. The material presented will provide sufficient knowledge for students to evaluate hydrologic processes associated with environmental systems and to develop conceptual evaluations that are part of water and natural resource assessments. Learning objectives: 1. Describe basic mechanisms and variables of hydrologic fluxes and states 2. Describe and define different mathematical formulations of hydrologic fluxes and states 3. Understand key components of a watershed model 4. Analyze, synthesize and interpret hydrologic data.

Credit Hours: 3
Prerequisites: MATH 1100 or MATH 1400 or STAT 1300 or consent of the instructor

BIOL_EN 7470: Biomolecular Engineering and Nanobiotechnology
(cross-leveled with BIOL_EN 4470, BME 4470). 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

BIOL_EN 7480: Physics and Chemistry of Materials
(same as PHYSCS 7190, NU_ENG 7319, CHEM 7490; cross-leveled with BIOL_EN 4480, PHYSCS 4190, NU_ENG 4319, CHEM 4490, BME 4480). 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

BIOL_EN 7540: Neural Models and Machine Learning
(same as CMP_SC 7540, ECE 7540; cross-leveled with BIOL_EN 4540, CMP_SC 4540, ECE 4540, BME 4540). 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 + at least Junior standing, or consent of instructor
Recommended: Introductory software programming, and introductory cell biology or consent of instructor

BIOL_EN 7560: Observing the Earth from Space
(same as ENV_SC 7560; cross-leveled with BIOL_EN 4560, ENV_SC 4560). This course provides an understanding of the theory and application of earth observing satellite remote sensing as a tool for environmental engineering and science. The topics include the fundamentals of electromagnetic radiation, satellite and sensor technology, integration of satellite and GIS data and digital image analysis. The lectures and homework assignments at the beginning of the course provide the necessary foundation to work with satellite imagery. Students will receive training with advanced image processing software and data acquisition techniques. The course will also cover case studies using remote sensing and image analysis techniques to answer real-world problems. The lectures and homework assignments include applications in forest management, land use change detection, monitoring agricultural activities, water and air quality monitoring, climate studies, and ecology and infectious diseases. The course will cover lectures on advanced remote sensing techniques towards the end of the course. Students will work on their independent projects during the last three weeks, applying remote sensing techniques to satellite images.

Credit Hours: 3
Prerequisites: MATH 1100 or MATH 1400 or STAT 1300 or consent of the instructor

BIOL_EN 7570: Fluorescent Imaging
(cross-leveled with BIOL_EN 4570, BME 4570). Principles and applications of fluorescent imaging. The course covers: Image formation in microscope; Fundamentals of fluorescence and fluorescent microscopy; molecular and cellular fluorescent imaging. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: BIO_SC 1500 and BIOL_EN 2180 or instructor's consent

BIOL_EN 7590: Computational Neuroscience
(same as BIO_SC 7590, ECE 7590, CMP_SC 7590, PSYCH 7591; cross-leveled with BIO_SC 4590, BIOL_EN 4590, BME 4590, CMP_SC 4590, ECE 4590, PSYCH 4591). An interdisciplinary course with a strong foundation in quantitative science for students in biological-behavioral science. Graded on A-F basis only.

Credit Hours: 4
Prerequisites: BIO_SC 1010, BIO_SC 1500; MATH 1500

BIOL_EN 7770: Biomedical Optics
(cross-leveled with BIOL_EN 4770, BME 4770). 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 and BIOL_EN 3180; or instructor's consent

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BIOL_EN 7970: Nuclear Magnetic Resonance and Magnetic Resonance Imaging
(cross-leveled with BIOL_EN 4970, BME 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. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: MATH 1500, PHYSCS 2750, PHYSCS 2760

BIOL_EN 7972: Engineering in Medical Imaging I: Non-Ionizing Techniques
(cross-leveled with BME 4972, BIOL_EN 4972). 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)

BIOL_EN 7973: Engineering in Medical Imaging II: Ionizing Techniques
(cross-leveled with BME 4973, BIOL_EN 4973). 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/BME 4972

BIOL_EN 7974: Medical Image Processing
(cross-leveled with BIOL_EN 4974, BME 4974). This course is designed to provide an exploration into medical image processing, encompassing a comprehensive understanding of foundational principles and algorithms inherent to medical imaging. This will include fundamental concepts in medical images, image enhancement, image segmentation and image registration. We will also dig into MRI modality, emphasizing critical components like Fourier Transform, Motion Correction, the integration of Artificial Intelligence within MRI Image Processing, Clinical Applications and Case Studies. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: MATH 1500
Recommended: BIOL_EN 2080 or BME 2080, ECE 4655 or ECE 7655, MATH 4140 or MATH 7140

BIOL_EN 8000: Scientific Discovery Leading to Life Science Innovations
(same as MPP 8000). The goal of this course is to provide participants with a conceptual and practical understanding of how life science research is conducted in a modern research institution in the US and the pathways involved in translating fundamental discoveries into products and services that affect healthcare. We will cover the transitions from initial discovery concepts to first-in-human studies, clinical trials, healthcare guidelines and policy to product development. We will provide an introduction to essential disciplines and interactions that enable scientific discoveries to move forward into novel device and drug

therapies. Participants will come away with a very complete picture of how medical research happens, including: how it is funded; what is required to make discoveries and record and protect intellectual property that is created; how to advance innovations to clinical practice, how to navigate the regulatory and bioethical environment, and how discoveries reach practitioners and benefit patients. The Course is the first in a three course sequence leading to a Graduate Certificate in Life Science Innovation and Entrepreneurship. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: Must be Graduate Standing or receive certificate program director's approval

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BIOL_EN 8001: Advanced Topics in Biological Engineering
Study of advanced developments in biological engineering.

Credit Hour: 1-3

BIOL_EN 8004: Regulatory Issues in Clinical Research and Clinical Trials
(same as MPP 8004). The goal of the course is to highlight key FDA regulatory issues for conducting human clinical trials and clinical research. For clinical trials, FDA has set up several compliance programs and guidance documents as a part of human subject protection (HSP)/ Bioresearch Monitoring (BIMO) initiatives. The aim of the program was to strengthen FDA oversight and protection of subjects in clinical trials and to preserve confidentiality of data. The HSP/BIMO initiative comprehends all FDA regulated clinical trials including human drugs and biological drug products, devices, foods, and veterinary medicine. The course is designed for students in medical professions, management, biomedical engineering, and related areas. Adequate knowledge regarding FDA guidance in conducting human clinical trials and clinical research will help professionals steer drug/device development and commercialization in their respective field. This course will be offered online only. An introduction to essential disciplines for conducting clinical trials and clinical research will be provided. The basics of good clinical practices (GCPs), biostatistics and clinical epidemiology in relation to clinical trials will be presented. Several relevant case studies for conducting clinical trials, both nationally and internationally, will be discussed. The importance of data collection and data management while conducting clinical trials will be explained. Graded on A-F basis only.

Credit Hours: 3
Recommended: Knowledge in biomedical sciences, clinical sciences

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BIOL_EN 8085: Problems in Biological Engineering
Supervised individual study at the graduate level.

Credit Hour: 1-99
Prerequisites: departmental consent

BIOL_EN 8087: Seminar in Biological Engineering
(same as CH_ENG 8087). Recent investigations in biological engineering and related fields. Discussion of current literature; preparation and presentation of papers. Graded on A-F basis only.

Credit Hour: 1

BIOL_EN 8088: Biological Engineering Graduate Seminar Continuation
(same as CH_ENG 8088). Seminar for graduate students enrolled in Biological Engineering program. Features invited speakers from external to university as well as graduate student presentations. Graded on S/U basis only.

Credit Hours: 0

BIOL_EN 8100: Design and Development of Biomedical Innovations
(same as ENGINR 8100, MPP 8100). 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

BIOL_EN 8170: Sensors and Biosensors
The course covers basic principles of chemical and biological sensors, such as immobilization techniques, transducers (optical, electrical, etc.) and performance factors.

Credit Hours: 3

BIOL_EN 8180: Numerical Methods in Engineering Research
Numerical techniques and case studies in Biological Engineering. Topics include basic numerical methods, mathematical representation of data, matrix algebra, ordinary and partial differential equations.

Credit Hours: 3

Prerequisites: MATH 4100

BIOL_EN 8200: Commercialization of Life Science Innovations
(same as MANGMT 8200). This course will provide educational content and experiences that equip course participants to navigate the main pathways for commercialization of biomedical innovations. Students will also learn how to access sources of capital for R&D and develop an understanding of the role of FDA approval and the processes for approval of different types of biomedical products. Students will become familiar with quality assurance programs required in the biomedical industry. Students will also become familiar with the most common business models for biomedical companies and the importance of product development and commercialization alliances.

Credit Hours: 3

BIOL_EN 8230: Advanced Ceramic Materials
(same as CH_ENG 8230, MAE 8230). To provide an advanced level understanding between processing, properties, and microstructure of ceramic materials. Topics include crystallography, defect chemistry, transport properties, microstructure, and forming methods. Graded on A-F basis only.

Credit Hours: 3

BIOL_EN 8250: Water Management Theory
Advanced studies in erosion control, irrigation, and drainage. Water resources engineering.

Credit Hours: 3
Prerequisites: MATH 1500, Computer Engineering and Computer Science course, SOIL 4307 or SOIL 7307 and Soil Conservation course

BIOL_EN 8280: Advanced Biological Transport Processes
Principles of fluid flow, heat transfer, and mass transfer applied to (a) understanding of how the human body functions (from the cellular up to the system level) and (b) designing biomedical devices. An independent project/case-study of a relevant research topic also required.

Credit Hours: 3

BIOL_EN 8370: Materials Characterization Techniques
Concepts and techniques in characterizing materials, including bulk and surface analyses. Techniques are presented in terms of use, sample requirements, and the engineering principles. Topics include: contact angle measurement, XPS, SEM, TEM, STM, AFM, XRD, and thermal analyses.

Credit Hours: 3
Prerequisites: at least one undergraduate course in material science, engineer, or design

BIOL_EN 8402: Research Methods
(same as F_S 8402). Review of literature; planning research projects; publication procedures.

Credit Hours: 2

BIOL_EN 8470: Ultrasensitive Biodetection
Multiplexing single-molecule, single-cell, nanobiotech analytical techniques to improve disease diagnosis, treatment, and understanding of biophenomena (membrane transport, gene expression, enzyme activities, cell communications). Graded A-F only.

Credit Hours: 3
Prerequisites: Instructor's consent required

BIOL_EN 8570: Microscopic Imaging
Advanced topics in microscopic imaging with focus on applications of molecular and cellular imaging using fluorescent microscopy.

Credit Hours: 3
Prerequisites: BIOL_EN 7570 or instructor's consent

BIOL_EN 8615: Atomistic Materials Analytics
(same as DATA_SCI 8615, CH_ENG 8615, ECE 8615, CHEM 8615, CMP_SC 8615, MAE 8615). Introduction to the principles of materials characterization and analysis leading to information extraction from experimental and computational data sets. Examines theoretical and practical issues associated with understanding the relationships between atomic/molecular structure and material properties. Describes encoding and visualizing atomic structure information. Measurement techniques covered include Ultraviolet-Visible (UV-Vis) spectroscopy, (Fourier Transform) Infrared Spectroscopy (FTIR), X-ray diffraction (XRD), and electronic conductivity. Covers standard data processing techniques, including sparse vs. abundant data, preprocessing and normalization, fixed length vs. variable length data, heterogeneous data streams, feature extraction, and the role of simulated data. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: DATA_SCI 7010, DATA_SCI 8010, Instructor consent required

BIOL_EN 8670: Orthopaedic Failure Modes and Effect Analysis
Engineering sciences will be leveraged provide a comprehensive study of failure modes and related effects for orthopaedic devices, orthopaedic tissue repair, and surgical interventions. Clinical case studies will be analyzed to introduce real world problems of orthopaedic failures. Graded on A-F basis only.

Credit Hours: 3

Prerequisites: BIOL_EN 3170 or ENGINR 1200, BIOL_EN 4370 or BIOL_EN 7370 or instructor consent
Recommended: For department majors

BIOL_EN 8870: Molecular and Cell Mechanics
Application of mechanics and engineering principles to biological systems at the cellular and molecular levels. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: ENGINR 2200

BIOL_EN 8970: Nuclear Magnetic Resonance and Magnetic Resonance Imaging
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. Graded on A-F basis only.

Credit Hours: 3

BIOL_EN 8990: Masters Thesis Research in Biological Engineering
Independent investigation to be presented as a thesis. Graded on S/U basis only.

Credit Hour: 1-15

BIOL_EN 9990: Doctoral Dissertation Research in Biological Engineering
Independent investigation to be presented as a thesis. Graded on S/U basis only.

Credit Hour: 1-99
