BIOE - BIOENGINEERING

BIOE Class Schedule (https://courses.illinois.edu/schedule/DEFAULT/DEFAULT/BIOE/)

Courses

BIOE 100   Bioengineering Seminar   credit: 1 Hour. (https://courses.illinois.edu/schedule/terms/BIOE/100/)
Bioengineering Seminar provides a broad introduction to the field, practice, and curriculum of Bioengineering. The major goals are for students to (1) meet the department faculty, (2) understand the curriculum and the 4-year goals, (3) understand and apply technologies central to the field through individual and group projects, (4) begin independent explorations into technologies in the field, and (5) practice teamwork, technical writing, and presentation. The course is designed for first-year Bioengineering majors.

BIOE 120   Introduction to Bioengineering   credit: 1 Hour. (https://courses.illinois.edu/schedule/terms/BIOE/120/)
Lectures and discussions of recent trends in bioengineering; topics typically include biological interaction with ultrasound and microwave radiation, modeling, instrumentation, biomaterials, biomechanics, biological heat and mass transfer, and medical imaging techniques.

BIOE 198   Special Topics   credit: 1 to 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/198/)
Subject offerings related to Bioengineering intended to augment the Bioengineering curriculum. See class schedule or course information websites for topics and prerequisites. May be repeated to a maximum of 8 hours, if topics vary. Prerequisite: Restricted to majors only.

BIOE 199   Undergraduate Open Seminar   credit: 1 to 5 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/199/)
May be repeated.

BIOE 200   Bioengineering Career Immersion   credit: 1 Hour. (https://courses.illinois.edu/schedule/terms/BIOE/200/)
This course provides exposure to Bioengineering careers through experiences in medicine, industry, and research. Students will observe professional practices to facilitate problem-based discoveries and technology design. Prerequisite: BIOE 120. Majors only.

BIOE 201   Conservation Principles Bioeng   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/201/)
Material, energy, charge, and momentum balances in biological problems. Steady-state and transient conservation equations for mass, energy, charge, and momentum will be derived and applied to mathematically analyze physiological systems using basic mathematical principles, physical laws, stoichiometry, and thermodynamic properties. Prerequisite: CHEM 104, MCB 150, and PHYS 211.

BIOE 202   Cell & Tissue Engineering Lab   credit: 2 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/202/)
Principles of cell biology inherent in tissue engineering design. Lab experience in safely and skillfully manipulating cells of the four tissue types and performing various quantitative analyses on products produced by cells that have differentiated. Prerequisite: MCB 150, and credit or concurrent enrollment in BIOE 206.

BIOE 205   Signals & Systems in Bioengrg   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/205/)
Introduction to signals and linear systems with examples from biology and medicine. Linear systems and mathematical models of systems, including differential equations, convolution, Laplace transforms, Fourier series and transforms, and discrete representations. Class examples and coursework apply general techniques to problems in biological signal analysis, including circuits, enzyme kinematics, and physiological system analysis. Use of Matlab and Simulink software to understand more complex systems. Prerequisite: CS 101 or CS 124, PHYS 212, and credit or concurrent registration in MATH 285.

BIOE 206   Cellular Bioengineering   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/206/)
Molecular and cellular biology focusing on instrumentation and measurement techniques: gene expression, translation, and regulation; cellular energetics and enzyme kinetics; membrane transport and cell signaling; cytoskeleton and the cell cycle; cell biology fundamentals emphasizing modern imaging and measurement systems to quantify cellular function. Credit is not given for both BIOE 206 and MCB 252. Prerequisite: MCB 150.

BIOE 210   Linear Algebra for Biomedical Data Science   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/210/)
Using analytical and computational tools from linear algebra, students will Solve large systems of linear equations, systems of linear ODEs, and linear PDEs; Analyze large, multivariable datasets to quantify relationships between variables; Decompose complex datasets into simpler representations; Introduce and solve common problems in classification, image processing, and machine learning; Develop a geometric understanding of high-dimensional spaces. Prerequisite: CS 101 or CS 124, and MATH 231.

BIOE 297   Individual Study   credit: 1 to 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/297/)
Special project or reading activity. May be repeated in the same or separate terms to a maximum of 12 hours. Prerequisite: Approved written application to department as specified by department or instructor.

BIOE 298   Special Topics   credit: 1 to 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/298/)
Subject offerings of new and developing areas of knowledge in bioengineering intended to augment the existing curriculum. See Class Schedule or departmental course information for topics and prerequisites. May be repeated to a maximum of 8 hours, if topics vary.

BIOE 302   Modeling Human Physiology   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/302/)
Description, quantification, and modeling of human physiological systems, based on systems fundamentals. Components, relationships, and homeostatic controls of neural, musculoskeletal, respiratory, cardiovascular, endocrine, digestion, and renal-filtration systems. Application of mathematical modeling and MATLAB simulation to further understanding of the systems and relate physiological consequences to changes in environment or component function. Prerequisite: BIOE 205 and one of MCB 252 or BIOE 206.

BIOE 303   Quantitative Physiology Lab   credit: 2 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/303/)
Experiments involving the modeling and measurement of animal and human physiology systems. Use of computer simulations to provide mathematical descriptions of physiology behavior. Calibration and validation of models through hands-on experiments. Focus on quantitative measurement of neural, cardiovascular, respiratory, muscular, and endocrine system functions. Prerequisite: Concurrent enrollment in BIOE 302 is allowed.

BIOE 306   Biofabrication Lab   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/306/)
Experiments involving design of bioreactors and microfluidic systems, advanced cell culture, and quantitative analysis techniques such as polmerase chain reaction and atomic force microscopy. Laboratory techniques relating to current literature and state of the art in the field of bioengineering. Prerequisite: BIOE 202. Departmental approval required for non-majors.

BIOE 310   Computational Tools for Biological Data   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/310/)
Fundamental and applied statistics, including probability distributions, parameter estimation, descriptive statistics, hypothesis testing, and linear regression. Statistical methods in genomics including sequence analysis, gene expression data analysis, human genomic variation, regulatory genomics, and cancer genomics. Credit is not given towards graduation for both BIOE 310 and IE 300. Prerequisite: BIOE 210 or MATH 257. Students in the BS-BIOE must take BIOE 210 as the prerequisite.

BIOE 360   Transport & Flow in Bioengrg   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/360/)
Fundamentals of fluid dynamics and mass transport applied to analysis of biological systems. Quantitative understanding of microscopic to macroscopic phenomena in biological systems related to their sensing by imaging techniques. Molecular phenomena in both healthy tissue and disease using examples from cardiovascular problems and cancer using ultrasound, optical and MRI techniques. Credit is not given for both BIOE 360 and any of CHBE 421, CHBE 451, or TAM 335. Prerequisite: BIOE 201 and MATH 285.

BIOE 380   Biomedical Imaging   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/380/)
Same as ECE 380. See ECE 380.

BIOE 397   Individual Study   credit: 1 to 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/397/)
Special project or reading activity. May be repeated up to 8 hours in a term to a maximum of 12 total hours. Prerequisite: Approved written application to department as specified by department or instructor.

BIOE 398   Special Topics   credit: 1 to 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/398/)
Subject offerings of new and developing areas of knowledge in bioengineering intended to augment the existing curriculum. See Class Schedule or departmental course information for topics and prerequisites. May be repeated to a maximum of 8 hours, if topics vary.

BIOE 400   Bioengineering Senior Design   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/400/)
Students perform market research and explore entrepreneurship in bioengineering resulting in the design of a device or process; practice problem identification and analyze solutions for real-world problems from the perspective of value added for end-users; use principles of design, engineering analysis, and customer discovery. This course emphasizes effective teamwork and technical communication; integrates intellectual property, United States Food and Drug Administration Quality System Regulation and Design Controls, human-centered design, FDA regulation, professionalism, and ethics. 4 undergraduate hours. No graduate credit. Prerequisite: BIOE 302, BIOE 303, BIOE 414, BIOE 415. Restricted to students in the Bioengineering Bachelor of Science program.
This course satisfies the General Education Criteria for:
Advanced Composition

BIOE 404   CS+BIOE Senior Design   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/404/)
This capstone design course is the culmination of the CS+BIOE curriculum. The course focuses on the design of computational technologies for needs in human health and in the life sciences. Students will perform market research, develop a prototype software, and explore entrepreneurship at the interface of bioengineering and computer science. Students will practice problem identification and the analysis of solutions for real world problems from the perspective of value added for end-users. Students will use principles of design, engineering analysis, and customer discovery. This course emphasizes effective teamwork and technical communication, and integrates content related to intellectual property, quality, human factors, FDA regulation, professionalism, and ethics. The overall goal of the course is to prepare students for careers using computational approaches in healthcare, biotechnology, life sciences, and pharmaceutical industries. 4 undergraduate hours. No graduate credit. Prerequisite: CS 374, BIOE 310, BIOE 206 or BIOE 302. Concurrent enrollment in CS 357 or CS 421. Restricted to CS + BIOE majors only.

BIOE 414   Biomedical Instrumentation   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/414/)
Engineering aspects of the detection, acquisition, processing, and display of signals from living systems; biomedical sensors for measurements of biopotentials, ions and gases in aqueous solution, force, displacement, blood pressure, blood flow, heart sounds, respiration, and temperature; therapeutic and prosthetic devices; medical imaging instrumentation. Same as ECE 414. 3 undergraduate hours. 3 graduate hours. Prerequisite: BIOE 205, ECE 205 or ECE 210.

BIOE 415   Biomedical Instrumentation Lab   credit: 2 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/415/)
Laboratory to accompany BIOE 414. Use of sensors and medical instrumentation for static and dynamic biological inputs. Measurement of biomedical signals. Same as ECE 415. 2 undergraduate hours. 2 graduate hours. Prerequisite: Credit or concurrent registration in BIOE 414.

BIOE 416   Biosensors   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/416/)
Same as ECE 416. See ECE 416.

BIOE 420   Intro Bio Control Systems   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/420/)
Systems engineering approach to modeling physiological systems to examine natural biological control systems, homeostasis, and control through external medical devices. Introduces open loop and closed loop feedback control; Laplace and Fourier analysis of system behavior; impulse and steady state responses; physiological modeling and system identification; and stability. Includes biological systems for endocrine function, muscle position, neuronal circuits, and cardiovascular function. Mathematical modeling, Matlab and Simulink simulation, and physiological measurements to relate control systems to maintenance of internal environment. 3 undergraduate hours. No graduate credit. Credit is not given for BIOE 420 if credit for AE 353, ECE 486, SE 320, or ME 340 has been earned. Prerequisite: BIOE 302, BIOE 303, BIOE 414, BIOE 415.

BIOE 424   Preclinical Molecular Imaging   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/424/)
Students will gain a solid educational foundation in the principles and practice of preclinical molecular imaging such that students can build on their prior education, training, and experiences to drive the field in new directions and advance their professional goals. The course will focus on key areas of knowledge: imaging physics and instrumentation, molecular probes and contrast agents, molecular interactions, quantitative imaging and modeling, and translation to the clinical imaging of disease. 3 undergraduate hours. 4 graduate hours. Credit is not given toward graduation for BIOE 424 and either BIOE 498 WD or BIOE 598 WD. Prerequisite: BIOE 205 is recommended.

BIOE 427   Biomedical Ultrasound Imaging   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/427/)
Same as ECE 472. See ECE 472.

BIOE 430   Intro Synthetic Biology   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/430/)
Introduction to the field of synthetic biology. Engineering applications of biomolecular systems and cellular capabilities for a variety of application biological background of gene regulation, experimental methods for circuit engineering, and mathematical basis for circuit modeling. Examples in biofuels, biomedicine, and other areas will be discussed. 3 undergraduate hours. 4 graduate hours. Prerequisite: BIOE 206 or MCB 252; and MATH 285.

BIOE 432   Systems Biology: Uncovering Design Principles of Biological Networks   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/432/)
Systems biology is the study of systems of biological components that may be molecules, cells, organisms or entire species. The behaviors of such systems often requires holistic, quantitative measurements and modeling of the entire groups of interacting components. This course offers an introduction to the fundamental concepts and quantitative methodologies underlying systems biology through the examination of a series of examples. It outlines basic design principles ubiquitous in biological networks. 3 undergraduate hours. 4 graduate hours. Prerequisite: MATH 285 or equivalent knowledge.

BIOE 434   Immunoengineering   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/434/)
Students will explore the field of immunoengineering, including basic and translational research for disease intervention and management, with rigorous investigation of the design principles underlying immunologically-based therapies and diagnostics. Students will learn to critically analyze scientific findings and develop effective written and oral communication skills through lectures, literature discussions, in-class activities, and a project requiring students to develop and present novel solutions to address limitations in existing technology in the field. 3 undergraduate hours. 4 graduate hours. Credit is not given toward graduation for BIOE 434 and either BIOE 498 AL or BIOE 598 AL. Prerequisite: Background in advanced biology or related field.

BIOE 450   Introduction to Quantitative Pharmacology   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/450/)
The interaction between living organisms and substances (drugs) that impact physiology and disease are the focus areas of this course. Concepts are integrated across equilibrium thermodynamics, kinetics, mass transfer, organic chemistry, biochemistry, and structural biology to understand drug design and function. Students will develop skills in quantitative aspects of medicinal chemistry, pharmacodynamics, and pharmacokinetics through mathematical models and computer simulations. 3 undergraduate hours. 4 graduate hours. Credit is not given toward graduation for BIOE 450 and either BIOE 498 QP or BIOE 598 QP. Prerequisite: CS 101 or CS 124, CHEM 232 or CHEM 236, MCB 150, MATH 231.

BIOE 460   Gene Editing Lab   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/460/)
The objective of this course is to provide the knowledge and hands-on experience required for both designing and building tools that are necessary to engineer biological systems at the molecular and cellular levels. This particular course will highlight diverse examples of applications in synthetic biology. It will deal with such topics as gene editing, epigenome engineering, regulation of gene expression and synthetic life. Projects will be assigned for small teams. Students will submit a report after completion of each project. Students will have the opportunity to independently design and execute a genetic engineering project and present their project to the class. 3 undergraduate hours. No graduate credit. Prerequisite: BIOE 202 and BIOE 206. For bioengineering undergraduate majors only.

BIOE 461   Cellular Biomechanics   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/461/)
Same as TAM 461. See TAM 461.

BIOE 467   Biophotonics   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/467/)
Same as ECE 467. See ECE 467.

BIOE 476   Tissue Engineering   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/476/)
Tissue engineering therapies for cell-based, material-based, and therapeutic-based solutions. Stem cells, immunology, and clinical applications. 3 undergraduate hours. 3 graduate hours. Prerequisite: MCB 150 and BIOE 206.

BIOE 479   Cancer Nanotechnology   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/479/)
An elective course for undergraduate students who are interested in learning nanotechnology and its applications in biology and medicine. Key topics include: (1) cancer biology and clinical oncology, (2) fundamentals of nanoscience, (3) principles of nanoscale engineering, (4) major classes of nanoparticles and nanostructures, and (5) nanomedicine - technologies and applications 3 undergraduate hours. No graduate credit. Approved for Letter and S/U grading. Prerequisite: BIOE 206, CHEM 232.

BIOE 480   Magnetic Resonance Imaging   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/480/)
Same as ECE 480. See ECE 480.

BIOE 481   Whole-Body Musculoskel Biomech   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/481/)
Same as ME 481. See ME 481.

BIOE 482   Musculoskel Tissue Mechanics   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/482/)
Same as ME 482. See ME 482.

BIOE 483   Biomedical Computed Imaging Systems   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/483/)
The frontier of biomedical imaging is computed imaging where multi-dimensional images must be reconstructed from measured data that is otherwise not meaningful to human observers. In this course, computational image reconstruction techniques will be developed and employed across a broad range of radiographic, magnetic resonance, and nuclear imaging modalities. General imaging and detection principles common to all computational modalities will be covered in context of specific biomedical imaging scenarios. X-ray computed tomography will be covered in depth and in the context of the imaging science principles presented the co-requisites; this also includes practical concerns about computing resources and modern GPU-based computing. The physics of magnetic resonance imaging will be presented and related to specific mathematical issues of image reconstruction and under-sampled measurement space. Positron emission tomography (PET) will be covered and specific clinical issues discussed in terms of reconstruction algorithm and parameter choices. 3 undergraduate hours. 4 graduate hours. Prerequisite: BIOE 205, BIOE 210, ECE 380/BIOE 380. Concurrent enrollment in BIOE 485 and BIOE 580; or instructor approval.

BIOE 484   Statistical Analysis of Biomedical Images   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/484/)
Biomedical image data often come in extreme numbers: there is either so many of them that humans can't analyze them in reasonable time (e.g., three-dimensional light sheet microscopy data) or they are few, highly varied and of limited spatial and intensity resolutions (e.g., positron emission tomography scans). Furthermore, the extraction of image features and the characterization of modality-dependent background noise can be particularly challenging in typical biomedical scenarios. In this course, several applications of statistical learning to biomedical image data will be covered in depth from first principles. Analyses will be done in Python using the Scikit-learn package and all homework assignments comprise statistical analyses of biomedical image data in real decision scenarios. Histogram transforms and the fundamental properties of image texture will be introduced and revisited throughout the course. The extraction of both low- and high-order spatial features at multiple scales will be demonstrated and employed throughout the course. Support vector machines will be introduced and applied to image classification and interpretation tasks. The random forest algorithm will be introduced and used on a number of large- and small-data tasks. Multiple linear regression will be applied to neuroimaging data and some common methods of assessing model robustness shown. Cross-validation of image-derived decisions and some common methods of assessing model robustness will be shown. Feature selection and dimensionality will be discussed in terms of diagnostic task performance. The effects of inter-feature correlation upon prediction confidence will be discussed. Principal component analysis will be described and applied to various image processing tasks. Unsupervised clustering and cluster analysis of extracted image features will be introduced. Stochastic object models will be introduced and applied in various validation tasks. 3 undergraduate hours. 4 graduate hours. Prerequisite: BIOE 485 or permission of the instructor. Students are expected to be familiar with calculus, basic probability & sampling, vector spaces, matrix algebra and constrained optimization. Several NumPy objects and manipulations will be reviewed, and all necessary Sci-kit functions introduced; however, students are expected to have substantial experience with Python programming as the basics of such will not be covered.

BIOE 485   Computational Mathematics for Machine Learning and Imaging   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/485/)
Covers fundamental mathematical and computational methods needed to implement computational imaging and machine learning solutions. First, relevant aspects of probability theory, matrix decompositions, and vector calculus will be introduced. Subsequently, methods that underline approximate inference, such as stochastic sampling methods, are introduced. Finally, numerical optimization methods that represent core components of computed imaging and machine learning will be introduced. This will include numerical optimization-based formulations of inverse problems. An emphasis will be placed on first order deterministic and stochastic gradient-based methods. Second order optimization techniques including quasi-Newton and Hessian free methods will also be surveyed. The application of these methods to computed imaging and machine learning problems will be addressed in detail. 4 undergraduate hours. 4 graduate hours. Prerequisite: Restricted to senior undergraduate or graduate standing in an engineering degree program or consent of instructor.

BIOE 486   Applied Deep Learning for Biomedical Imaging   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/486/)
Covers basic concepts, methodology and algorithms in deep learning and their applications to solve various biomedical imaging problems. Introduction to neural networks and their application to supervised and unsupervised learning problems formulated for biomedical imaging will be provided. Connections between general learning methodologies and specific challenges in the field of biomedical imaging, and design, implementation and evaluation of deep neural network-based solutions to imaging problems will be emphasized. Problems covered will include imaging system design and optimization, image recovery and reconstruction (built on the imaging physics and system course – BIOE 483), image processing (e.g., denoising, super-resolution and enhancement) and image analysis (e.g., same-contrast, multi-contrast and multimodal image registration, segmentation, classification and quality assessment). Biomedical application specific problems and solutions will be covered via hands-on problems and team-based projects. 3 undergraduate hours. 4 graduate hours. Prerequisite: MATH 241 or equivalent; BIOE 210, MATH 415 or equivalent; BIOE 310, ECE 310, STAT 410 or equivalent; BIOE 198, CS 101 or equivalent; BIOE 483; BIOE 485; or consent of the instructor.

BIOE 487   Stem Cell Bioengineering   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/487/)
Stem Cell Bioengineering will provide a foundation in the application of engineering approaches for the quantitative analysis of stem cell biology and the translation of stem cells into therapies. There will be 4 main sections of the course; (i) Stem Cell Basics, (ii) Stem Cell Genetics, (iii) Stem Cell Microenvironments, and (iv) Stem Cell Applications. The course will be targeted for first year graduate students and senior-level undergraduate students. The course will use a lecture and discussion format to effectively present relevant information. 3 undergraduate hours. 4 graduate hours. Prerequisite: BIOE 476.

BIOE 488   Applied High-Performance Computing for Imaging Science credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/488/)
Will introduce students to basic principles and practical applications of scientific computing as they relate to problems in machine learning and computed imaging. In this self-contained course, students will be introduced to a variety of important topics that underlie real-world machine learning and biomedical image computing tasks that are not typically comprised in a single course. The material will be presented in a practical way that will be accessible to engineering students who have a moderate level of experience in scientific computing but lack specific training in computer science. The emphasis will be on immediate applicability of scientific computing techniques as opposed to theoretical knowledge. The course will begin with an overview of good scientific coding practices in Python and introductions to canonical computing architectures. Subsequently, parallel computing concepts will be surveyed that address multi-core CPU and GPU-enabled systems. Distributed GPU computing on a cluster will also be covered. The salient aspects of TensorFlow and/or other relevant machine learning programming environments will be introduced and utilized in applications of machine learning. 3 undergraduate hours. 3 graduate hours. Prerequisite: Familiarity with the Python programming language. Restricted to students with senior undergraduate or graduate standing in an engineering major.

BIOE 489   Regulations, Ethics and Logistics in Biomedical Applications of Machine Learning   credit: 3 or 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/489/)
The application of machine learning (ML) to medical image data is an area of intense, well-funded research. Due to practical logistics, however, the ideas expounded in published research articles do not necessarily translate perfectly into clinical implementation. The purposeful design and assessment of machine learning experiments will be introduced and revisited throughout the course. The financial cost of training, data acquisition and expert labelling will be considered in the context of product delivery. Some relevant university, corporate and governmental regulatory policies will be presented by expert guest lecturers. Specific issues of clinical implementation and adoption of new technology will be covered. The ethics of using images influenced or analyzed by ML in patient care and/or medical research will be explored in depth. Topics include: diagnosis accuracy, mandated system upgrades, informed consent, patient privacy, researcher/vendor liability and the role and reliability of federal regulations in ethical application of ML to biomedical data. The policies and procedures of NIH study sections and internal review boards will be highlighted and some key issues related to intellectual property will be surveyed. 3 undergraduate hours. 4 graduate hours. Prerequisite: Restricted to students with senior undergraduate or graduate standing and familiarity with machine learning principles.

BIOE 497   Individual Study   credit: 1 to 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/497/)
Special project or reading activity. 1 to 4 undergraduate hours. 1 to 4 graduate hours. May be repeated up to 8 hours in a term to a maximum of 12 total hours. Prerequisite: Approved written application to department as specified by department or instructor.

BIOE 498   Special Topics   credit: 1 to 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/498/)
Subject offerings of new and developing areas of knowledge in bioengineering intended to augment the existing curriculum. See Class Schedule or departmental course information for topics and prerequisites. 1 to 4 undergraduate hours. 1 to 4 graduate hours. May be repeated if topics vary.

BIOE 499   Senior Thesis   credit: 1 to 5 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/499/)
Limited in general to seniors in the curriculum in bioengineering. Any others must have the consent of the department chief advisor. Each student taking the course must register in a minimum of 5 hours either in one term or divided over two terms. 1 to 5 undergraduate hours. No graduate credit. May be repeated to a maximum of 10 hours between two semesters. Prerequisite: Senior Standing.

BIOE 500   Graduate Seminar   credit: 0 or 1 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/500/)
Lecture surveying a broad range of Bioengineering topics. Approved for S/U grading only. May be repeated in separate terms to a maximum of 4 hours.

BIOE 501   Seminar Discussion   credit: 1 Hour. (https://courses.illinois.edu/schedule/terms/BIOE/501/)
Familiarization with reading and discussing academic journals in Bioengineering. Approved for S/U grading only.

BIOE 502   Bioengineering Professionalism   credit: 2 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/502/)
Ethical questions and conduct, procedures, and professional standards in the practice of bioengineering. Authorship and mentoring, use of animal and human subjects, conflict of interest, ethical behavior in scientific research, intellectual property, and approval processes for drugs and biomedical devices.

BIOE 504   Analytical Methods in Bioeng   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/504/)
Mathematical concept relating to modeling of physiological and bio-molecular processes and the instrumentation used to measure those processes. Review of matrix methods, probability, linear systems, and integral transforms. Singular value decomposition, Bayesian decision making, and linear system solutions to ordinary differential equations. Application of concepts to biosensor design and evaluation, tracer kinetic modeling, and filtering and curve-fitting approaches to forward modeling problems. Prerequisite: MATH 285.

BIOE 505   Computational Bioengineering   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/505/)
Mathematical and statistical models plus accompanying computational techniques central to many aspects of systems biology and bioengineering research. Theory of supervised and unsupervised learning; linear models; dimension reduction; Monte Carlo computation; analysis of gene expression data and genome sequence data; modeling of gene transcription network signaling pathways. Same as CSE 505. Prerequisite: STAT 400.

BIOE 507   Advanced Bioinstrumentation   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/507/)
Instrumentation and underlying theory employed in bioengineering. Concepts in the design and operation of sensors, fundamentals of optics, basic control theory and systems, digital components, and fundamental principles of medical imaging techniques. Specific knowledge of one biomedical instrument or system will be emphasized including detailed mathematical analysis. Prerequisite: BIOE 504.

BIOE 510   Computational Cancer Biology   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/510/)
Mathematical modeling of the process of carcinogenesis as somatic cell evolution. Focus on current research topics in cancer biology using data from next-generation sequencing technologies. Overview of database resources and algorithmic and modeling methods relating to biological problems. Prerequisite: BIOE 206, CS 101, MATH 285.

BIOE 516   Advanced Biosensors   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/516/)
Same as ECE 514. See ECE 514.

BIOE 526   Advances in Biotechnology   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/526/)
From protein design to genetic engineering and regenerative medicine to spatial omics, Advances in Biotechnology will expose students to many of the cutting-edge technologies that are revolutionizing the study of biological systems and the detection and treatment of diseases. Prerequisite: Knowledge equivalent to an advanced molecular and cellular biology course is recommended.

BIOE 570   Seminar Series   credit: 1 Hour. (https://courses.illinois.edu/schedule/terms/BIOE/570/)
Guest topics will vary, but will typically cover topics of current interest relevant to the bioengineering field. Lecture and discussion on topics relevant to the development, regulatory approval, marketing, and application of systems used in the fields of biomedical imaging, life science research, and pharmaceutical discovery. Emphasis upon case studies on topics that will include regulatory approval, intellectual property, strategy, and technology innovation. Approved for S/U grading only. May be repeated up to 2 hours in separate terms. Prerequisite: For students enrolled in the M.Eng. in Bioengineering degree program.

BIOE 571   Biological Measurement I   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/571/)
With special focus on medical imaging, this course will introduce fundamental concepts related to the detection and analysis of biological analytes, biomedical images, and physiological parameters. Topics include signal-to-noise analysis, noise characterization, data aliasing, analog-to-digital conversion, common strategies for noise reduction, exogenous contrast agents and fundamentals of molecular imaging. The fundamental phenomena behind biological measurements such as DNA sequencing, fluorescence microscopy. MRI imaging, OCT imaging, and ultrasound imaging will be discussed along with the factors that influence noise and contrast from the standpoint of fundamental physics, instrumentation/hardware, and post-measurement data/signal processing. Prerequisite: For students enrolled in the M.Eng in Bioengineering degree program.

BIOE 572   Biological Measurement II   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/572/)
With special focus on medical imaging, learn about advanced techniques relating to state-of-the-art bioinstrumentation technologies. Topics will broadly include fluorescence, genomic and proteomic diagnostics, biosensors, ultrasound imaging, microscopy and their uses relevant to physiological changes related to major human diseases. Prerequisite: BIOE 571. For students enrolled in the M.Eng in Bioengineering degree program.

BIOE 573   Managing Business Operations   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/573/)
Introduction to fundamental principles of design, management, and improvement of business operations and product innovations. Strategies and techniques for managing processes, projects, process improvement and new product development. Prerequisite: For students enrolled in the M.Eng in Bioengineering degree program.

BIOE 574   Innovation and Introduction to Financial Decision Making   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/574/)
Tools, concepts, and analytical frameworks that enhance the ability to define and analyze strategic problems stemming from innovation and technological change, and to identify sources of competitive advantage from both an industry and firm-level perspective. Introduction to financial decision making, including topics in valuation, project analysis and risk-return relationships. Prerequisite: For students enrolled in the M.Eng. in Bioengineering degree program only.

BIOE 575   Capstone Project   credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/575/)
Students in the Master of Engineering (M.Eng.) in Bioengineering program will demonstrate their proficiency through a capstone project, where students will work on a translational project to develop solutions for real world problems utilizing principles of design, engineering analysis, and functional operation of engineering systems. Depending on the student's flexibility and availability, capstone projects may include collaboration with other online M.Eng. students on a team-based project, analysis of case studies, or even a self-directed project that directly relates to a specific area of interest or on behalf of their employer. Project presentations and demonstrations may be required at the end of the program. May be repeated for 6 hours in separate semesters. Students in the Master of Engineering program will be required to sign up for BIOE 575 in both the Fall and Spring semesters. Prerequisite: Proficiency in MATLAB and completion of or concurrent enrollment in core classes required for the Master of Engineering (M.Eng.) in Bioengineering program. Class only available to students in the M.Eng. in Bioengineering degree program.

BIOE 580   Foundations of Imaging Science   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/580/)
Exposes students to a broad treatment of the mathematical and statistical principles of biomedical imaging. In addition to providing a foundation for understanding general principles of image formation and objective image quality assessment that are widely applicable, this material will be essential for the principled and successful application of artificial intelligence methods in biomedical imaging. This course will cover the mathematical concepts needed for the deterministic analysis of imaging systems. Linear operator theory will be employed to describe continuous-to-continuous, continuous-to-discrete, and discrete-to-discrete mappings from objects to images. In addition, imaging systems will be analyzed in a statistical framework where stochastic models for objects and images will be introduced. Methodologies for objective assessment of image quality (OAIQ) will be introduced, which will address classification tasks, receiver operator characteristic (ROC) analysis, and salient aspects estimation theory. An introduction to numerical observers for quantification of OAIQ will be provided. Prerequisite: Concurrent enrollment in BIOE 485 and BIOE 483; or instructor approval. Restricted to students with graduate standing or consent of instructor.

BIOE 586   Deep Generative Models in Bioimaging   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/586/)
A generative model is a powerful way of learning any kind of data distribution using unsupervised learning and they have achieved tremendous success in recent years. In the context of biomedical imaging, generative models are being actively explored for many important and diverse applications that include image and video synthesis, representation learning and semi-supervised learning, domain adaptation, text to image synthesis, image compression, super-resolution, inpainting, saliency prediction, image enhancement, style transfer and texture synthesis, and image-to-image translation. Generative models also hold great potential for regularizing inverse problems that arise in biomedical image formation. This course will provide an introduction to the use of deep neural networks for generative modeling in the context of biomedical image science. An emphasis will be placed on variational autoencoders (VAEs) and generative adversarial networks (GANs), as these are currently two of the most commonly employed and efficient approaches. The use of generative models for exploring data-acquisition designs optimizing the performance of imaging systems will also be introduced. Practical details regarding the successful training and evaluation of deep generative models using biomedical image data will introduced throughout the course. This will be reinforced via homework assignments and a final project that require hands-on training of networks facilitated by allocations of GPU time. Prerequisite: BIOE 486, BIOE 485, BIOE 483, BIOE 580 or consent of instructor.

BIOE 588   Biomedical Image Computing Capstone Project Literature Review   credit: 1 Hour. (https://courses.illinois.edu/schedule/terms/BIOE/588/)
This journal-club style course will expose students to the modern literature on biomedical imaging and machine learning. Students will be exposed to cutting edge topics in the rapidly evolving field of biomedical image computing. Additionally, the course will prepare students for the capstone project in the Biomedical Image Computing MS degree program that will take place in the third semester of the program. During this course, students will interact with potential project mentors and engage in detailed literature reviews related to potential projects. Approved for S/U grading only. Prerequisite: Graduate student standing. Concurrent enrollment in BIOE 484 and BIOE 486 is required. Restricted to students in the Biomedical Image Computing M.S. degree program only.

BIOE 589   Biomedical Image Computing Capstone Project   credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/589/)
In this course students will complete a project that utilizes machine learning methods and advanced computational tools to solve a problem related to bioimaging. The projects will utilize experimental bioimage data that is contributed by a project sponsor and/or available via open source databases. While these projects need not be publishable or perfectly novel, they will involve the systematic application and evaluation of machine learning and image computing methods. It is expected that, by solving actual problems posed by industry or clinical partners, students will gain marketable experience but, ideally, also will make inroads with their future employers. Prerequisite: BIOE 588, BIOE 484, BIOE 486, BIOE 580. Concurrent enrollment in BIOE 489 is required. Restricted to students enrolled in the Biomedical Image Computing MS degree program only.

BIOE 597   Individual Study   credit: 1 to 8 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/597/)
Special project or reading activity. May be repeated. Prerequisite: Approved written application to department as specified by department or instructor.

BIOE 598   Special Topics   credit: 1 to 4 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/598/)
Subject offerings of new and developing areas of knowledge in bioengineering intended to augment the existing curriculum. See Class Schedule or departmental course information for topics and prerequisites. May be repeated in the same or separate terms if topics vary.

BIOE 599   Thesis Research   credit: 0 to 16 Hours. (https://courses.illinois.edu/schedule/terms/BIOE/599/)
Bioengineering graduate thesis research. Approved for S/U grading only. May be repeated in separate terms.