

BIOMEDICAL ENGINEERING, BACHELOR OF SCIENCE

Students seeking a B.S. degree focus their engineering electives on one of seven subspecialties that incorporates traditional engineering disciplines and biomedical applications. See the Biomedical Engineering Undergraduate website (<https://www.bme.jhu.edu/undergraduate/>) for additional information.

Program Requirements

(See also General Requirements for Departmental Majors (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/undergraduate-policies/academic-policies/requirements-bachelors-degree/>).

The B.S. degree in biomedical engineering requires 129 credits. The courses listed below must either be taken or passed by examination for advanced credit. All courses used to satisfy degree requirements must be taken for a grade (no satisfactory/unsatisfactory grading may be counted). No more than 6 credits of engineering, science, or mathematics courses in which a grade of D was received may be counted.

Code	Title	Credits
Basic Sciences ¹		
AS.171.101	General Physics: Physical Science Major I	4
or AS.171.107	General Physics for Physical Sciences Majors (AL)	
AS.171.102	General Physics: Physical Science Major II	4
or AS.171.108	General Physics for Physical Science Majors (AL)	
AS.173.111	General Physics Laboratory I	1
AS.173.112	General Physics Laboratory II	1
AS.030.101	Introductory Chemistry I	3
AS.030.102	Introductory Chemistry II	3
AS.030.105	Introductory Chemistry Laboratory I	1
AS.030.106	Introductory Chemistry Laboratory II	1
Mathematics ²		
AS.110.108	Calculus I (Physical Sciences & Engineering)	4
AS.110.109	Calculus II (For Physical Sciences and Engineering)	4
AS.110.202	Calculus III	4
or AS.110.211	Honors Multivariable Calculus	
EN.553.291	Linear Algebra and Differential Equations	4
Select one of the following:		3-4
EN.553.310	Probability & Statistics for the Physical Sciences & Engineering	
EN.553.311	Probability and Statistics for the Biological Sciences and Engineering	
EN.553.413	Applied Statistics and Data Analysis	
EN.553.430	Introduction to Statistics	
EN.553.433	Monte Carlo Methods	
Humanities and Social Sciences		
Select courses to form a coherent program, relevant to the student's goals, with at least one course at the 300-level or higher. ³		18
Biomedical Core		
EN.580.111	Biomedical Engineering and Design	2
EN.580.151	Structural Biology of Cells	3

EN.580.153	Structural Biology of Cells Laboratory	1
EN.580.221	Biochemistry and Molecular Engineering	4
EN.580.241	Statistical Physics	2
EN.580.242	Biological Models and Simulations	2
EN.580.243	Linear Signals and Systems	2
EN.580.244	Nonlinear Dynamics of Biological Systems	2
EN.580.246	Systems and Controls	2
EN.580.248	Systems Biology of the Cell	2
EN.580.475	Biomedical Data Science	2
EN.580.477	Biomedical Data Science Laboratory	1
EN.580.485	Computational Medicine: Cardiology	2
EN.580.487	Computational Medicine: Cardiology Laboratory	1
Select two of the following core electives: ⁴		6
EN.580.424	Neuroengineering and Lab	
EN.580.427	Microphysiological Systems and Laboratory	
EN.580.452	Cell and Tissue Engineering Lab	
EN.580.453	Immunoengineering Principles and Applications	
EN.580.454	Methods in Nucleic Acid Sequencing Lab	
EN.580.494	Build an Imager	
Career Exploration in BME ⁵		
Focus Area		
Select one of the following:		21
Biomedical Data Science (p. 3)		
Computational Medicine (p. 4)		
Genomics and Systems Biology (p. 4)		
Imaging and Medical Devices (p. 5)		
Immunoengineering (p. 6)		
Neuroengineering (p. 7)		
Translational Cell and Tissue Engineering (p. 8)		
Design ⁶		
Select at least one of the following design sequences:		6
EN.510.433	Senior Design Research	
& EN.510.434	and Senior Design/Research II (This option must be approved by the Materials Science & Engineering Department)	
EN.520.363	ECE Ideation and Design Lab ⁷	
EN.520.463	ECE Ideation and Design Lab ⁷	
EN.540.421	Project in Design: Pharmacodynamics	
& EN.540.432	and Project in Design: Pharmacokinetics	
EN.580.311	Design Team Health-Tech Project I	
& EN.580.312	and Design Team Health-Tech Project II	
EN.580.411	Design Team Health-Tech Project I	
& EN.580.412	and Design Team Health-Tech Project II	
EN.580.437	Neuro Data Design I	
& EN.580.438	and Neuro Data Design II	
EN.580.456	Introduction to Rehabilitation Engineering	
& EN.580.457	and Introduction to Rehabilitation Engineering: Design Lab	
or EN.585.71 Rehabilitation Engineering II		
EN.580.471	Principles of Design of BME Instrumentation	
& EN.580.571	and Honors Instrumentation ⁸	
EN.580.480	Precision Care Medicine I	
& EN.580.481	and Precision Care Medicine II	

EN.601.455 Computer Integrated Surgery I
& EN.601.456 and Computer Integrated Surgery II
or EN.601.496 Computer Integrated Surgery II - Teams

EN.660.345 Multidisciplinary Engineering Design 1
& EN.660.346 and

Computer Programming

EN.500.112 Gateway Computing: JAVA 3
or EN.500.113 Gateway Computing: Python
or EN.500.114 Gateway Computing: Matlab

Free Electives

Select 9 credits from any area. This can include Intersession S/U 9
courses as well as other courses taken for S/U or grade and not used
to fulfill another requirement.

¹ Students who receive credit for AP Physics I and/or Physics II will receive a waiver for the laboratory course. This will reduce the required number of credits for Basic Sciences by 1 or 2 credits. Students are still required to complete at least 129 total credits for the degree.

² Students who take an approved math course and receive 3 credits will have a total of 19 credits. Students are still required to complete at least 129 total credits for the degree.

³ One course in which ethical and social issues related to technology or medicine is recommended. and at least two semesters of writing-intensive courses, see Writing Requirement (<https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/undergraduate-policies/academic-policies/requirements-bachelors-degree/#writingtext>).

⁴ These courses cannot be double-counted toward the 21-credit focus area requirement. Courses taken in excess of the 6 credit core elective requirement can be counted in a relevant focus area.

⁵ Career Exploration in BME is a 0-credit self-identified set of career related events (lectures, panels, journal clubs, etc.) beginning in the spring semester of year one and continuing until graduation. Career Exploration is administered through a learning management site; students will be enrolled by the department.

⁶ Each 2-semester sequence must be taken in its entirety.

⁷ Course EN.520.363 (juniors) and EN.580.463 (seniors) must be taken in a fall/spring or spring/fall sequence and for a total of 2 semesters to satisfy the BME design requirement. Students interested in longitudinal involvement may take the course up to 5 times.

⁸ EN.580.571 (2 credits) is offered during the spring semester. Instructor permission required.

Focus Areas

Building on the foundation of the core curriculum, each student is required to take a cohesive sequence of advanced engineering encompassing one of seven Biomedical Engineering focus areas. A student's choice of focus area is made during the sophomore year and is based on their experience with the Biomedical Engineering Core and how they wish to apply their skill, knowledge, and passion:

Biomedical Data Science—involves the analysis of large-scale biomedical datasets to understand how living systems function. Our academic and research programs in Biomedical Data Science center on developing new data analysis technologies in order to understand disease mechanisms and provide improved health care at lower costs. Our curriculum in Biomedical Data Science trains students to extract knowledge from biomedical datasets of all sizes in order to understand and solve health-related problems. Students collaborate with faculty throughout the schools of Medicine and Engineering to develop novel cloud-based

technologies and data analysis methods that will improve our ability to diagnose and treat diseases.

Computational Medicine—aims to advance health care by developing computational models of disease, personalizing these models using data from patients, and applying these models to improve the diagnosis and treatment of disease. We are using these patient models to discover novel risk biomarkers, predict disease progression, design optimal treatments, and identify new drug targets for applications such as cancer, cardiovascular disease, and neurological disorders. Our curriculum in Computational Medicine bridges biology with mathematics, engineering, and computational science. Students develop new solutions in personalized medicine by building computational models of the molecular biology, physiology, and anatomy of human health and disease.

Genomics and Systems Biology—connects the information in our genome and epigenome to the function of biological systems, from cells to tissues and organs. We are developing new computational and experimental methods for systematic analysis of genomes, building models that span length and time scales, and using synthetic biology to design new biomedical systems for human health applications. Our curriculum spans the fields of engineering, computer science, biology, and biostatistics. Students develop tools to understand the genetic, molecular, and cellular behaviors that cause disease.

Imaging and Medical Devices—involves the measurement of spatiotemporal distributions over scales ranging from molecules and cells to organs and whole populations. Grounded in mathematics, physics, and biological systems, our academic and research programs in Imaging & Medical Devices center on data-intensive image analysis and new imaging technologies that include optics, ultrasound, X-ray/CT, MRI, and molecular imaging. Our curriculum in Imaging & Medical Devices spans fundamental development of imaging technologies, incorporation of these technologies into instruments, and translation into the clinic. In addition to collecting anatomical data, students learn to use data analysis and computer simulations to generate functional images that allow physicians to understand organs and tissues from the smallest scale to the systems level.

Immunoengineering—harnesses the power of the immune system to treat diseases such as cancer and promote tissue regeneration and healing. Our curriculum trains students in immunoengineering at the molecular, cellular, and systems levels. Particular emphasis is placed on novel materials and methods to harness the body's immune system to fight disease, and to promote tissue repair and healing. Students develop new biomaterials, vaccines, therapeutics, and systems to understand immune cell function and guide immune cell behavior.

Neuroengineering—comprises fundamental, experimental, computational, theoretical, and quantitative research aimed at understanding and augmenting brain function in health and disease across multiple spatiotemporal scales. Our curriculum in Neuroengineering trains students to develop and apply new technologies to understand and treat neurological disorders. Students build tools to define, control, enhance, or inhibit neural networks in precise spatial and temporal domains.

Translational Cell and Tissue Engineering—develops and translates advanced technologies to enhance or restore function at the molecular, cellular, and tissue levels. Hopkins BME is leading an effort in translational cell and tissue engineering that bridges discovery, innovation, and translation through basic science, engineering, and clinical endeavors. Our curriculum spans a variety of novel methods that harness the power of cells, materials, and advanced therapeutics

to promote tissue repair and to treat disease. Students develop new techniques and biomaterials to guide cell behavior and reconstruct damaged tissues and organs.

Courses in a focus area must be taken for a total of 21 or more credits. At least 15 credits must come from the relevant upper-level engineering course list; a maximum of six credits from the non-upper-level engineering course lists may be used. Please refer to www.bme.jhu.edu/undergraduate/resources.htm (<https://www.bme.jhu.edu/academics/undergraduate/undergraduate-focus-areas-courses/>) for applicable courses designed for each focus area by faculty members with research interests appropriate to the area; all faculty members are active participants in shaping the undergraduate curriculum.

Biomedical Data Science Focus Area

Code	Title	Credits
Upper-Level Engineering Courses		
EN.520.344	Introduction to Digital Signal Processing	3
EN.520.385	Signals, Systems, & Learning	3
EN.520.412	Machine Learning for Signal Processing	3
EN.520.414	Image Processing & Analysis	3
EN.520.415	Image Process & Analysis II	3
EN.520.432	Medical Imaging Systems	3
EN.520.447	Information Theory	3
EN.530.410	Biomechanics of the Cell	3
EN.540.409	Dynamic Modeling and Control	4
EN.540.414	Computational Protein Structure Prediction and Design	3
EN.540.421	Project in Design: Pharmacodynamics	3
EN.540.432	Project in Design: Pharmacokinetics	3
EN.540.468	Introduction to Nonlinear Dynamics and Chaos	3
EN.553.361	Introduction to Optimization	4
EN.553.362	Introduction to Optimization II	4
EN.553.371	Cryptology and Coding	4
EN.553.385	Numerical Linear Algebra	4
EN.553.386	Scientific Computing: Differential Equations	4
EN.553.391	Dynamical Systems	4
EN.553.400	Mathematical Modeling and Consulting	4
EN.553.401	Introduction to Research	3
EN.553.413	Applied Statistics and Data Analysis	4
EN.553.420	Introduction to Probability	4
EN.553.426	Introduction to Stochastic Processes	4
EN.553.430	Introduction to Statistics	4
EN.553.433	Monte Carlo Methods	4
EN.553.436	Introduction to Data Science	4
EN.553.450	Computational Molecular Medicine	4
EN.553.463	Network Models in Operations Research	4
EN.553.467	Deep Learning in Discrete Optimization	3
EN.553.472	Graph Theory	4
EN.553.488	Computing for Applied Mathematics	3
EN.553.492	Mathematical Biology	3
EN.553.493	Mathematical Image Analysis	4
EN.553.630	Introduction to Statistics	4
EN.553.720	Probability Theory I	4
EN.553.721	Probability Theory II	4

EN.553.730	Statistical Theory	4
EN.553.731	Statistical Theory II	3
EN.580.431	Introduction to Computational Medicine: Imaging	2
EN.580.433	Introduction to Computational Medicine: The Physiome	2
EN.580.437	Neuro Data Design I	4
EN.580.438	Neuro Data Design II	4
EN.580.439	Models of the Neuron	4
EN.580.447	Computational Stem Cell Biology	3
EN.580.460	Epigenetics at the Crossroads of Genes and the Environment	1.5
EN.580.462	Representations of Choice	3
EN.580.464	Advanced Data Science for Biomedical Engineering	4
EN.580.480	Precision Care Medicine I	4
EN.580.481	Precision Care Medicine II	4
EN.580.488	Foundations of Computational Biology and Bioinformatics	3
EN.580.491	Learning, Estimation and Control	3
EN.580.709	Sparse Representations in Computer Vision and Machine Learning	3
EN.601.315	Databases	3
EN.601.318	Operating Systems	3
EN.601.320	Parallel Programming	3
EN.601.350	Genomic Data Science	3
EN.601.402	Digital Health and Biomedical Informatics	1
EN.601.415	Databases	3
EN.601.433	Intro Algorithms	3
EN.601.434	Randomized and Big Data Algorithms	3
EN.601.443	Security & Privacy in Computing	3
EN.601.446	Sketching and Indexing for Sequences	3
EN.601.447	Computational Genomics: Sequences	3
EN.601.448	Computational Genomics: Data Analysis	3
EN.601.454	Augmented Reality	3
EN.601.455	Computer Integrated Surgery I	4
EN.601.456	Computer Integrated Surgery II	3
EN.601.457	Computer Graphics	3
EN.601.461	Computer Vision	3
EN.601.463	Algorithms for Sensor-Based Robotics	3
EN.601.464	Artificial Intelligence	3
EN.601.465	Natural Language Processing	4
EN.601.466	Information Retrieval and Web Agents	3
EN.601.474	ML: Learning Theory	3
EN.601.475	Machine Learning	3
EN.601.476	Machine Learning: Data to Models	3
EN.601.477	Causal Inference	3
EN.601.482	Machine Learning: Deep Learning	4
EN.601.491	Human-Robot Interaction	3
Contact the department advising office for course additions.		
200-Level Engineering Courses		
A maximum of 3 credits from this list may count in focus area		
EN.580.212	Design Team Health-Tech Project II	3
EN.580.298	Advanced Design Team	3

EN.601.226	Data Structures	4
EN.601.229	Computer System Fundamentals	3

Non Upper-Level Engineering Courses

A maximum of 3 credits from this list may count in focus area

EN.580.112	Design Team Health-Tech Project II	3
EN.580.211	Design Team Health-Tech Project I	3
EN.601.231	Automata & Computation Theory	3
AS.110.311	Methods of Complex Analysis	4
AS.110.405	Real Analysis I	4
AS.110.421	Dynamical Systems	4
AS.110.443	Fourier Analysis	4

Students may use a maximum of 3 research credits (courses coded EN.XXX.5XX) as a non-upper-level engineering course.

Computational Medicine Focus Area

Code	Title	Credits
------	-------	---------

Upper-Level Engineering Courses

EN.520.315	Intro. to Bio-Inspired Processing of Audio-Visual Signals	3
EN.520.385	Signals, Systems, & Learning	3
EN.520.432	Medical Imaging Systems	3
EN.530.343	Design and Analysis of Dynamical Systems	3
EN.530.410	Biomechanics of the Cell	3
EN.530.676	Locomotion Dynamics & Control	3
EN.540.421	Project in Design: Pharmacodynamics	3
EN.540.432	Project in Design: Pharmacokinetics	3
EN.553.361	Introduction to Optimization	4
EN.553.386	Scientific Computing: Differential Equations	4
EN.553.391	Dynamical Systems	4
EN.553.420	Introduction to Probability	4
EN.553.426	Introduction to Stochastic Processes	4
EN.553.430	Introduction to Statistics	4
EN.553.436	Introduction to Data Science	4
EN.553.450	Computational Molecular Medicine	4
EN.580.430	Systems Pharmacology and Personalized Medicine	4
EN.580.431	Introduction to Computational Medicine: Imaging	2
EN.580.433	Introduction to Computational Medicine: The Physiome	2
EN.580.437	Neuro Data Design I	4
EN.580.438	Neuro Data Design II	4
EN.580.439	Models of the Neuron	4
EN.580.447	Computational Stem Cell Biology	3
EN.580.460	Epigenetics at the Crossroads of Genes and the Environment	1.5
EN.580.462	Representations of Choice	3
EN.580.480	Precision Care Medicine I	4
EN.580.481	Precision Care Medicine II	4
EN.580.488	Foundations of Computational Biology and Bioinformatics	3
EN.580.491	Learning, Estimation and Control	3
EN.580.688	Foundations of Computational Biology and Bioinformatics	3
EN.601.350	Genomic Data Science	3

EN.601.447	Computational Genomics: Sequences	3
EN.601.448	Computational Genomics: Data Analysis	3
EN.601.455	Computer Integrated Surgery I	4
EN.601.456	Computer Integrated Surgery II	3
EN.601.461	Computer Vision	3
EN.601.475	Machine Learning	3
EN.601.476	Machine Learning: Data to Models	3
EN.601.482	Machine Learning: Deep Learning	4
EN.601.496	Computer Integrated Surgery II - Teams	3
EN.601.723	Advanced Topics in Data-Intensive Computing	3

Contact the department advising office for course additions.

200-Level Engineering Courses

A maximum of 3 credits from this list may count in focus area

EN.580.212	Design Team Health-Tech Project II	3
EN.580.298	Advanced Design Team	3
EN.601.226	Data Structures	4
EN.601.229	Computer System Fundamentals	3
EN.601.231	Automata & Computation Theory	3

Non Upper-Level Engineering Courses

A maximum of 3 credits from this list may count in focus area

EN.580.112	Design Team Health-Tech Project II	3
EN.580.211	Design Team Health-Tech Project I	3

Students may use a maximum of 3 research credits (courses coded EN.XXX.5XX) as a non-upper-level engineering course.

Genomics and Systems Biology Focus Area

Code	Title	Credits
------	-------	---------

Upper-Level Engineering Courses

EN.510.311	Structure Of Materials	3
EN.510.316	Biomaterials I	3
EN.510.407	Biomaterials II: Host response and biomaterials applications	3
EN.510.436	Biomaterials for Cell Engineering	3
EN.520.315	Intro. to Bio-Inspired Processing of Audio-Visual Signals	3
EN.520.353	Control Systems	4
EN.520.385	Signals, Systems, & Learning	3
EN.520.414	Image Processing & Analysis	3
EN.520.415	Image Process & Analysis II	3
EN.520.432	Medical Imaging Systems	3
EN.520.454	Control Systems Design	3
EN.520.636	Feedback Control in Biological Signaling Pathways	3
EN.530.327	Introduction to Fluid Mechanics	3
EN.530.343	Design and Analysis of Dynamical Systems	3
EN.530.410	Biomechanics of the Cell	3
EN.530.414	Computer-Aided Design	3
EN.530.420	Robot Sensors/Actuators	4
EN.530.426	Biofluid Mechanics	3
EN.530.436	Bioinspired Science and Technology	3
EN.530.445	Introduction to Biomechanics	3
EN.530.446	Experimental Methods in Biomechanics	3
EN.530.448	Biosolid Mechanics	3
EN.540.303	Transport Phenomena I	3

EN.540.304	Transport Phenomena II	4
EN.540.409	Dynamic Modeling and Control	4
EN.540.414	Computational Protein Structure Prediction and Design	3
EN.540.421	Project in Design: Pharmacodynamics	3
EN.540.432	Project in Design: Pharmacokinetics	3
EN.553.361	Introduction to Optimization	4
EN.553.362	Introduction to Optimization II	4
EN.553.386	Scientific Computing: Differential Equations	4
EN.553.391	Dynamical Systems	4
EN.553.400	Mathematical Modeling and Consulting	4
EN.553.420	Introduction to Probability	4
EN.553.426	Introduction to Stochastic Processes	4
EN.553.430	Introduction to Statistics	4
EN.553.436	Introduction to Data Science	4
EN.553.450	Computational Molecular Medicine	4
EN.553.467	Deep Learning in Discrete Optimization	3
EN.570.351	Introduction to Fluid Mechanics	3
EN.580.418	Principles of Pulmonary Physiology	3
EN.580.430	Systems Pharmacology and Personalized Medicine	4
EN.580.431	Introduction to Computational Medicine: Imaging	2
EN.580.433	Introduction to Computational Medicine: The Physiome	2
EN.580.439	Models of the Neuron	4
EN.580.441	Cellular Engineering	3
EN.580.444	Biomedical Applications of Glycoengineering	3
EN.580.447	Computational Stem Cell Biology	3
EN.580.454	Methods in Nucleic Acid Sequencing Lab	3
EN.580.459	Seminar in Epigenetic Engineering	1
EN.580.460	Epigenetics at the Crossroads of Genes and the Environment	1.5
EN.580.464	Advanced Data Science for Biomedical Engineering	4
EN.580.471	Principles of Design of BME Instrumentation	4
EN.580.480	Precision Care Medicine I	4
EN.580.481	Precision Care Medicine II	4
EN.580.488	Foundations of Computational Biology and Bioinformatics	3
EN.580.491	Learning, Estimation and Control	3
EN.580.571	Honors Instrumentation	2
EN.580.625	Structure and Function of the Auditory and Vestibular Systems	3
EN.580.752	Advanced Topics in Regenerative and Immune Engineering	4
EN.580.688	Foundations of Computational Biology and Bioinformatics	3
EN.601.350	Genomic Data Science	3
EN.601.448	Computational Genomics: Data Analysis	3
EN.601.465	Natural Language Processing	4
EN.601.475	Machine Learning	3
EN.601.476	Machine Learning: Data to Models	3
EN.601.482	Machine Learning: Deep Learning	4

Contact the department advising office for course additions.

200-Level Engineering Courses

A maximum of 3 credits from this list may count in focus area

EN.520.214	Signals and Systems	4
EN.520.216	Introduction To VLSI	3
EN.520.230	Mastering Electronics	3
EN.520.231	Mastering Electronics Laboratory	2
EN.580.212	Design Team Health-Tech Project II	3
EN.580.298	Advanced Design Team	3
EN.601.226	Data Structures	4

Non Upper-Level Engineering Courses

A maximum of 3 credits from this list may count in focus area

AS.020.303	Genetics	3
AS.080.305	Neuroscience: Cellular and Systems I	3
EN.580.112	Design Team Health-Tech Project II	3
EN.580.211	Design Team Health-Tech Project I	3

Students may use a maximum of 3 research credits (courses coded EN.XXX.5XX) as a non-upper-level engineering course.

Imaging and medical devices Focus Area

Code	Title	Credits
Upper-Level Engineering Courses		
EN.510.311	Structure Of Materials	3
EN.510.313	Mechanical Properties of Materials	3
EN.510.314	Electronic Properties of Materials	3
EN.510.316	Biomaterials I	3
EN.510.403	Materials Characterization	3
EN.510.407	Biomaterials II: Host response and biomaterials applications	3
EN.510.422	Micro and Nano Structured Materials & Devices	3
EN.510.430	Biomaterials Lab	3
EN.520.315	Intro. to Bio-Inspired Processing of Audio-Visual Signals	3
EN.520.340	Introduction to Mechatronics: Sensing, Processing, Learning and Actuation	3
EN.520.344	Introduction to Digital Signal Processing	3
EN.520.349	Microprocessor Lab I	3
EN.520.353	Control Systems	4
EN.520.414	Image Processing & Analysis	3
EN.520.415	Image Process & Analysis II	3
EN.520.417	Computation for Engineers	3
EN.520.424	FPGA Synthesis Lab	3
EN.520.427	Design of Biomedical Instruments and Systems	3
EN.520.432	Medical Imaging Systems	3
EN.520.433	Medical Image Analysis	3
EN.520.435	Digital Signal Processing	3
EN.520.447	Information Theory	3
EN.520.448	Electronics Design Lab	3
EN.520.450	Advanced Micro-Processor Lab	3
EN.520.454	Control Systems Design	3
EN.520.483	Bio-Photonics Laboratory	3
EN.520.491	CAD Design of Digital VLSI Systems I (Juniors/Seniors)	3
EN.520.492	Mixed-Mode VLSI Systems	3

EN.520.495	Microfabrication Laboratory	4	EN.580.742	Neural Implants and Interfaces	3
EN.520.631	Ultrasound and Photoacoustic Beamforming	3	EN.601.315	Databases	3
EN.520.646	Wavelets & Filter Banks	3	EN.601.415	Databases	3
EN.520.651	Foundations of Probabilistic Machine Learning	4	EN.601.454	Augmented Reality	3
EN.530.381	Engineering Design Process	3	EN.601.455	Computer Integrated Surgery I	4
EN.530.414	Computer-Aided Design	3	EN.601.456	Computer Integrated Surgery II	3
EN.530.420	Robot Sensors/Actuators	4	EN.601.461	Computer Vision	3
EN.530.421	Mechatronics	3	EN.601.463	Algorithms for Sensor-Based Robotics	3
EN.530.424	Dynamics of Robots and Spacecraft	3	EN.601.475	Machine Learning	3
EN.530.441	Introduction to Biophotonics	3	EN.601.482	Machine Learning: Deep Learning	4
EN.530.445	Introduction to Biomechanics	3	EN.601.496	Computer Integrated Surgery II - Teams	3
EN.530.446	Experimental Methods in Biomechanics	3	Contact the department advising office for course additions.		
EN.530.468	Locomotion Mechanics: Fundamentals	3	200-Level Engineering Courses		
EN.530.473	Molecular Spectroscopy and Imaging	3	A maximum of 3 credits from this list may count in focus area		
EN.530.474	Effective and Economic Design for Biomedical Instrumentation	4	EN.520.214	Signals and Systems	4
EN.530.646	Robot Devices, Kinematics, Dynamics, and Control	4	EN.520.230	Mastering Electronics	3
EN.530.672	Biosensing & BioMEMS	3	EN.520.231	Mastering Electronics Laboratory	2
EN.540.403	Colloids and Nanoparticles	3	EN.530.241	Electronics & Instrumentation	3
EN.540.440	Micro/Nanotechnology: The Science and Engineering of Small Structures	3	EN.580.212	Design Team Health-Tech Project II	3
EN.553.361	Introduction to Optimization	4	EN.580.298	Advanced Design Team	3
EN.553.362	Introduction to Optimization II	4	EN.601.226	Data Structures	4
EN.553.391	Dynamical Systems	4	Non Upper-Level Engineering Courses		
EN.553.413	Applied Statistics and Data Analysis	4	A maximum of 3 credits from this list may count in focus area		
EN.553.420	Introduction to Probability	4	AS.110.405	Real Analysis I	4
EN.553.426	Introduction to Stochastic Processes	4	AS.110.443	Fourier Analysis	4
EN.553.430	Introduction to Statistics	4	EN.580.112	Design Team Health-Tech Project II	3
EN.553.436	Introduction to Data Science	4	EN.580.211	Design Team Health-Tech Project I	3
EN.553.433	Monte Carlo Methods	4	Students may use a maximum of 3 research credits (courses coded EN.XXX.5XX) as a non-upper-level engineering course.		
EN.553.472	Graph Theory	4	IMMUNoENGINEERING FOCUS AREA		
EN.553.493	Mathematical Image Analysis	4	Code	Title	Credits
EN.553.630	Introduction to Statistics	4	Upper-Level Engineering Courses		
EN.553.761	Nonlinear Optimization I	3	EN.510.311	Structure Of Materials	3
EN.553.762	Nonlinear Optimization II	3	EN.510.312	Thermodynamics/Materials	3
EN.580.425	Radiology for Engineers	3	EN.510.313	Mechanical Properties of Materials	3
EN.580.435	Applied Bioelectrical Engineering	3	EN.510.314	Electronic Properties of Materials	3
EN.580.456	Introduction to Rehabilitation Engineering	3	EN.510.315	Physical Chemistry of Materials II	3
EN.580.457	Introduction to Rehabilitation Engineering: Design Lab	3	EN.510.316	Biomaterials I	3
EN.585.717	Rehabilitation Engineering II	3	EN.510.403	Materials Characterization	3
EN.580.464	Advanced Data Science for Biomedical Engineering	4	EN.510.407	Biomaterials II: Host response and biomaterials applications	3
EN.580.471	Principles of Design of BME Instrumentation	4	EN.510.415	The Chemistry of Materials Synthesis	3
EN.580.571	Honors Instrumentation	2	EN.510.422	Micro and Nano Structured Materials & Devices	3
EN.580.479	Principles and Applications of Modern X-ray Imaging and Computed Tomography	3	EN.510.426	Biomolecular Materials I - Soluble Proteins and Amphiphiles	3
EN.580.491	Learning, Estimation and Control	3	EN.510.430	Biomaterials Lab	3
EN.580.493	Imaging Instrumentation	4	EN.510.435	Mechanical Properties of Biomaterials	3
EN.580.494	Build an Imager	3	EN.510.442	Nanomaterials Lab	3
EN.580.678	Biomedical Photonics I	4	EN.510.443	Chemistry and Physics of Polymers	3
EN.580.689	Modern Optical Microscopy: Theory and Practice	3	EN.520.495	Microfabrication Laboratory	4
EN.580.740	Surgery for Engineers	3	EN.530.410	Biomechanics of the Cell	3
			EN.530.426	Biofluid Mechanics	3

EN.530.436	Bioinspired Science and Technology	3
EN.530.445	Introduction to Biomechanics	3
EN.530.446	Experimental Methods in Biomechanics	3
EN.540.301	Kinetic Processes	4
EN.540.303	Transport Phenomena I	3
EN.540.304	Transport Phenomena II	4
EN.540.306	Chemical & Biomolecular Separation	4
EN.540.402	Metabolic Systems Biotechnology	3
EN.540.403	Colloids and Nanoparticles	3
EN.540.414	Computational Protein Structure Prediction and Design	3
EN.540.421	Project in Design: Pharmacodynamics	3
EN.540.422	Introduction to Polymeric Materials	3
EN.540.432	Project in Design: Pharmacokinetics	3
EN.540.440	Micro/Nanotechnology: The Science and Engineering of Small Structures	3
EN.540.465	Engineering Principles of Drug Delivery	3
EN.540.602	Metabolic Systems Biotechnology	3
EN.553.386	Scientific Computing: Differential Equations	4
EN.553.391	Dynamical Systems	4
EN.553.413	Applied Statistics and Data Analysis	4
EN.553.420	Introduction to Probability	4
EN.553.426	Introduction to Stochastic Processes	4
EN.553.430	Introduction to Statistics	4
EN.553.436	Introduction to Data Science	4
EN.553.433	Monte Carlo Methods	4
EN.553.450	Computational Molecular Medicine	4
EN.553.492	Mathematical Biology	3
EN.580.418	Principles of Pulmonary Physiology	3
EN.580.430	Systems Pharmacology and Personalized Medicine	4
EN.580.441	Cellular Engineering	3
EN.580.442	Tissue Engineering	3
EN.580.444	Biomedical Applications of Glycoengineering	3
EN.580.447	Computational Stem Cell Biology	3
EN.580.453	Immunoengineering Principles and Applications	3
EN.580.452	Cell and Tissue Engineering Lab	3
EN.580.464	Advanced Data Science for Biomedical Engineering	4
EN.580.488	Foundations of Computational Biology and Bioinformatics	3
EN.580.454	Methods in Nucleic Acid Sequencing Lab	3
EN.580.646	Molecular Immunoengineering	3
EN.580.752	Advanced Topics in Regenerative and Immune Engineering	4

Contact the department advising office for course additions.

200-Level Engineering Courses

A maximum of 3 credits from this list may count in focus area

EN.580.212	Design Team Health-Tech Project II	3
EN.580.298	Advanced Design Team	3

Non Upper-Level Engineering Courses

A maximum of 3 credits from this list may count in focus area

AS.020.303	Genetics	3
------------	----------	---

AS.020.337	Stem Cells & the Biology of Aging & Disease	2
AS.020.363	Developmental Biology	3
EN.580.112	Design Team Health-Tech Project II	3
EN.580.211	Design Team Health-Tech Project I	3

Students may use a maximum of 3 research credits (courses coded EN.XXX.5XX) as a non-upper-level engineering course.

Neuroengineering Focus Area

Code	Title	Credits
Upper-Level Engineering Courses		
EN.520.315	Intro. to Bio-Inspired Processing of Audio-Visual Signals	3
EN.520.344	Introduction to Digital Signal Processing	3
EN.520.349	Microprocessor Lab I	3
EN.520.353	Control Systems	4
EN.520.385	Signals, Systems, & Learning	3
EN.520.412	Machine Learning for Signal Processing	3
EN.520.424	FPGA Synthesis Lab	3
EN.520.432	Medical Imaging Systems	3
EN.520.445	Audio Signal Processing	3
EN.520.448	Electronics Design Lab	3
EN.520.450	Advanced Micro-Processor Lab	3
EN.520.454	Control Systems Design	3
EN.520.491	CAD Design of Digital VLSI Systems I (Juniors/Seniors)	3
EN.520.492	Mixed-Mode VLSI Systems	3
EN.520.495	Microfabrication Laboratory	4
EN.530.414	Computer-Aided Design	3
EN.530.420	Robot Sensors/Actuators	4
EN.530.421	Mechatronics	3
EN.530.445	Introduction to Biomechanics	3
EN.530.446	Experimental Methods in Biomechanics	3
EN.530.468	Locomotion Mechanics: Fundamentals	3
EN.530.646	Robot Devices, Kinematics, Dynamics, and Control	4
EN.530.672	Biosensing & BioMEMS	3
EN.540.403	Colloids and Nanoparticles	3
EN.540.440	Micro/Nanotechnology: The Science and Engineering of Small Structures	3
EN.580.424	Neuroengineering and Lab	3
EN.580.426	Neuroengineering: The Neural Control of Movement	3
EN.580.437	Neuro Data Design I	4
EN.580.438	Neuro Data Design II	4
EN.580.441	Cellular Engineering	3
EN.580.442	Tissue Engineering	3
EN.580.452	Cell and Tissue Engineering Lab	3
EN.580.456	Introduction to Rehabilitation Engineering	3
EN.580.457	Introduction to Rehabilitation Engineering: Design Lab	3
EN.585.717	Rehabilitation Engineering II	3
EN.580.471	Principles of Design of BME Instrumentation	4
EN.580.571	Honors Instrumentation	2
EN.580.488	Foundations of Computational Biology and Bioinformatics	3

EN.580.491	Learning, Estimation and Control	3
EN.580.493	Imaging Instrumentation	4
EN.580.494	Build an Imager	3
EN.580.688	Foundations of Computational Biology and Bioinformatics	3
EN.580.689	Modern Optical Microscopy: Theory and Practice	3
EN.580.742	Neural Implants and Interfaces	3
EN.601.455	Computer Integrated Surgery I	4
EN.601.456	Computer Integrated Surgery II	3
EN.601.475	Machine Learning	3
EN.601.482	Machine Learning: Deep Learning	4
EN.601.496	Computer Integrated Surgery II - Teams	3
Contact the department advising office for course additions.		
200-Level Engineering Courses		
A maximum of 3 credits from this list may count in focus area		
EN.520.214	Signals and Systems	4
EN.520.216	Introduction To VLSI	3
EN.520.230	Mastering Electronics	3
EN.530.254	Manufacturing Engineering	3
EN.580.212	Design Team Health-Tech Project II	3
EN.580.298	Advanced Design Team	3
Non Upper-Level Engineering Courses		
A maximum of 3 credits from this list may count in focus area		
EN.580.112	Design Team Health-Tech Project II	3
EN.580.211	Design Team Health-Tech Project I	3
Students may use a maximum of 3 research credits (courses coded EN.XXX.5XX) as a non-upper-level engineering course.		
translational cell and tissue Engineering Focus Area		
Code	Title	Credits
Upper-Level Engineering Courses		
EN.510.311	Structure Of Materials	3
EN.510.312	Thermodynamics/Materials	3
EN.510.313	Mechanical Properties of Materials	3
EN.510.314	Electronic Properties of Materials	3
EN.510.315	Physical Chemistry of Materials II	3
EN.510.316	Biomaterials I	3
EN.510.403	Materials Characterization	3
EN.510.407	Biomaterials II: Host response and biomaterials applications	3
EN.510.415	The Chemistry of Materials Synthesis	3
EN.510.422	Micro and Nano Structured Materials & Devices	3
EN.510.426	Biomolecular Materials I - Soluble Proteins and Amphiphiles	3
EN.510.430	Biomaterials Lab	3
EN.510.435	Mechanical Properties of Biomaterials	3
EN.510.436	Biomaterials for Cell Engineering	3
EN.510.442	Nanomaterials Lab	3
EN.510.443	Chemistry and Physics of Polymers	3
EN.520.495	Microfabrication Laboratory	4
EN.530.410	Biomechanics of the Cell	3
EN.530.426	Biofluid Mechanics	3
EN.530.436	Bioinspired Science and Technology	3
EN.530.445	Introduction to Biomechanics	3
EN.530.446	Experimental Methods in Biomechanics	3
EN.530.448	Biosolid Mechanics	3
EN.530.468	Locomotion Mechanics: Fundamentals	3
EN.530.474	Effective and Economic Design for Biomedical Instrumentation	4
EN.540.301	Kinetic Processes	4
EN.540.303	Transport Phenomena I	3
EN.540.304	Transport Phenomena II	4
EN.540.306	Chemical & Biomolecular Separation	4
EN.540.402	Metabolic Systems Biotechnology	3
EN.540.403	Colloids and Nanoparticles	3
EN.540.414	Computational Protein Structure Prediction and Design	3
EN.540.421	Project in Design: Pharmacodynamics	3
EN.540.422	Introduction to Polymeric Materials	3
EN.540.432	Project in Design: Pharmacokinetics	3
EN.540.440	Micro/Nanotechnology: The Science and Engineering of Small Structures	3
EN.540.465	Engineering Principles of Drug Delivery	3
EN.540.602	Metabolic Systems Biotechnology	3
EN.553.391	Dynamical Systems	4
EN.580.418	Principles of Pulmonary Physiology	3
EN.580.430	Systems Pharmacology and Personalized Medicine	4
EN.580.435	Applied Bioelectrical Engineering	3
EN.580.441	Cellular Engineering	3
EN.580.442	Tissue Engineering	3
EN.580.444	Biomedical Applications of Glycoengineering	3
EN.580.447	Computational Stem Cell Biology	3
EN.580.452	Cell and Tissue Engineering Lab	3
EN.580.453	Immunoengineering Principles and Applications	3
EN.580.454	Methods in Nucleic Acid Sequencing Lab	3
EN.580.456	Introduction to Rehabilitation Engineering	3
EN.580.457	Introduction to Rehabilitation Engineering: Design Lab	3
EN.585.717	Rehabilitation Engineering II	3
EN.580.643	Advanced Orthopaedic Tissue Engineering	3
EN.580.646	Molecular Immunoengineering	3
Contact the department advising office for course additions.		
200-Level Engineering Courses		
A maximum of 3 credits from this list may count in focus area		
EN.580.212	Design Team Health-Tech Project II	3
EN.580.298	Advanced Design Team	3
Non Upper-Level Engineering Courses		
A maximum of 3 credits from this list may count in focus area		
AS.020.303	Genetics	3
AS.020.337	Stem Cells & the Biology of Aging & Disease	2
AS.020.363	Developmental Biology	3
EN.580.112	Design Team Health-Tech Project II	3
EN.580.211	Design Team Health-Tech Project I	3

Students may use a maximum of 3 research credits (courses coded EN.XXX.5XX) as a non-upper-level engineering course.