BS in Biomedical Engineering

Degree Program Description

The Biomedical Engineering undergraduate degree program offers four tracks from which our students can develop their primary expertise: bioinformatics, biomedical imaging and instrumentation, biomaterials, and biomechanics. In collaboration with colleagues from the School of Medicine, the College of Veterinary Medicine, the College of Health Sciences, the Sinclair School of Nursing, the Honors College, and the College of Engineering, we develop students into engineering leaders with skills in creative and critical thinking, problem-solving, innovation, engineering design, communication, entrepreneurship, and team-building. Our award-winning faculty offer exceptional classes and research experiences for our students, and our flexible, tracked curriculum integrates easily with the pre-medicine and Honors Certificate programs, as well as a number of accelerated plans to earn a bachelor's plus a master's degrees at MU.

Biomedical engineering is a science-based engineering discipline that integrates engineering and biomedical sciences in one curriculum. The MU biomedical engineering program is a broad-based curriculum that prepares students for careers in traditional engineering as well as medicine, veterinary medicine, law, health care, policy, and academics. Biomedical engineering graduates are hired by biotechnology, medical, and pharmaceutical companies, as well as by government agencies and major research laboratories. Many of our undergraduate students attend graduate, medical, or law schools post-graduation. 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; many additionally take the MCAT, the LSAT, and the GRE in preparation for their graduate or professional studies.

Major Program Requirements

The curriculum encompasses basic sciences, social and behavioral sciences, humanities and fine arts, engineering sciences and topics, and program core courses. The core courses cover topics of biomedical engineering principles and design. In a capstone design course sequence, each student completes a design project under the direction of a faculty mentor. Technical electives allow students to place emphasis on biomaterials, biomechanics, bioinformatics, and biomedical imaging and instrumentation.

Students earning a Bachelor of Science in Biomedical Engineering are required to complete all University general education (http://catalog.missouri.edu/academicdegreerequirements/generaleducationrequirements/), University undergraduate requirements (http://catalog.missouri.edu/academicdegreerequirements/universityrequirements/), degree, and major requirements, including selected foundational courses, which may fulfill some University general education requirements. All pre-requisites required for Basic Engineering, Biomedical Engineering, and Technical Elective courses must be completed with a grade of C- or better. Courses designated a core biomedical engineering course must be completed with a grade of C- or better.

Students are also required to complete one 3-hour cultural awareness course which is selected from an approved cultural awareness course list, created and maintained by the College of Engineering or which meets the Arts and Science (A&S) diversity intensive (DI) requirement.

Major Core Requirements

General Requirements		**21**
ENGLSH 1000	Writing and Rhetoric	3
or ENGLSH 1000H	Honors Writing and Rhetoric	
Two courses that meet the campus designation for Writing Intensive requirements, with one at 3000 level or higher in your major.		
One course that meets the designation of a cultural awareness course (from approved list).		
Social and Behavioral Sciences		**9**
Economics (from approved list)		3
ECONOM 1014	Principles of Microeconomics (suggested as it meets the requirements for a cultural awareness course.)	
or ECONOM 1014H	Principles of Microeconomics-Honors	
History (from approved list)		3
Humanities and Fine Arts		**9**
Ethics (from approved list)		3
Suggested to have at least one course that meets requirements for Writing Intensive designation and at least one BS/SS or H/FA course at 2000 level or greater.		
Math and Statistics		**19**
MATH 1500	Analytic Geometry and Calculus I	5
MATH 1700	Calculus II	5
MATH 2300	Calculus III	3
MATH 4100	Differential Equations	3
STAT 4710	Introduction to Mathematical Statistics	3
Basic Sciences		**29**
BIO_SC 1500	Introduction to Biological Systems with Laboratory	5
PHYSCS 2750	University Physics I	5
PHYSCS 2760	University Physics II	5
CHEM 1320		4
CHEM 2100	Organic Chemistry I	3
Cell and Molecular Biology (from approved list)		4
Physiology (from approved list)		3
Basic Engineering		**18**
ENGINR 1000	Introduction to Engineering	1
ENGINR 1050	Foundations of Engineering	2
ENGINR 1200	Statics and Elementary Strength of Materials	3
ENGINR 2200	Intermediate Strength of Materials	3
Engineering Graphics (from approved list)		3
Fluid Mechanics (from approved list)		3
Thermodynamics (from approved list)		3
Biomedical Engineering Core		**17**
BME 2000	Professional Development in Engineering	2
BME 2080	Introduction to Programming for Engineers	3
or CMP_SC 1050	Algorithm Design and Programming I	
or INFOTC 1040	Introduction to Problem Solving and Programming	
NOTE: only students in the Bioinformatics Track can count CMP_SC 1050/INFOTC 1040		
BME 2180	Engineering Analysis of Bioprocesses	3

BME 3180	Heat and Mass Transfer in Biological Systems	3
BME 4380	Applied Electronic Instrumentation	4
BME 4980W	Biomedical Engineering Design - Writing Intensive	3
Technical Electives		**24**
Upper-level engineering courses, with 24 credit hours in a single track		24

Biomedical Engineering Tracks

Bioinformatics Track (2 Requisites, 6 Electives)		**24**
CS-Driven Path Requisites		
CMP_SC 2050	Algorithm Design and Programming II	4
CMP_SC 3380	Database Applications and Information Systems	3
IT-Driven (Big Data) Path Requisites		
INFOTC 2040	Programming Languages and Paradigms	3
INFOTC 3380	Database Systems and Applications	3
Track Electives		
Select 4-6 of the following:		
BME 4001	Topics in Biomedical Engineering (Medical Image Data Collection and Management)	3-9
BME 4003	Design and Development of Biomedical Innovation	3
BME 4075	Brain Signals and Brain Machine Interfaces	3
BME 4085	Problems in Biomedical Engineering	1-5
BME 4470	Biomolecular Engineering and Nanbiotechnology	3
or BME 4470H	Biomolecular Engineering and Nanobiotechnology - Honors	
BME 4540	Neural Models and Machine Learning	3
BME 4590	Computational Neuroscience	4
BME 4940	Engineering Internship	1-3
BME 4985	Bioengineering Design II	1-5
BME 4990	Undergraduate Research in Biomedical Engineering	1-6
BME 4995H	Undergraduate Honors Research in Biomedical Engineering	1-5
ECE 4655	Digital image Processing	3
ECE 4720	Introduction to Machine Learning and Pattern Recognition	3
Select up to 2 of the following:		
CMP_SC 4080	Parallel Programming for High Performance Computing	3
CMP_SC 4750	Artificial Intelligence I	3
CMP_SC 4770	Introduction to Computational Intelligence	3
CMP_SC 7010	Computational Methods in Bioinformatics	3
HMI 4431		3
HMI 4440		3

Biomedical Imaging & Instrumentation Track (1 Requisite, 7 Electives)		**24**
Track Requisite		
ENGINR 2100	Circuit Theory for Engineers	3
Track Electives		
Select from 3-5 of the following:		
BME 4075	Brain Signals and Brain Machine Interfaces	3
BME 4420/4001	Introduction to Biomedical Imaging (or BME 4001 Engineering in Medical Imaging)	3
BME 4570	Fluorescent Imaging	3
BME 4770	Biomedical Optics	3
BME 4970	Nuclear Magnetic Resonance and Magnetic Resonance Imaging	3
Select an additional 2-4 courses from the following, in addition to any not completed above:		
BME 4001	Topics in Biomedical Engineering (Medical Image Data Collection and Management)	3
BME 4003	Design and Development of Biomedical Innovation	3
BIOL_EN 4070	Bioelectricity	3
BME 4085	Problems in Biomedical Engineering	1-5
BME 4470	Biomolecular Engineering and Nanbiotechnology	3
or BME 4470H	Biomolecular Engineering and Nanobiotechnology - Honors	
BME 4540	Neural Models and Machine Learning	3
BME 4590	Computational Neuroscience	4
BME 4940	Engineering Internship	1-3
BME 4972	Engineering in Medical Imaging I: Non-Ionizing Techniques	3
BME 4973	Engineering in Medical Imaging II: Ionizing Techniques	3
BME 4985	Bioengineering Design II	1-5
BME 4990	Undergraduate Research in Biomedical Engineering	1-6
BME 4995H	Undergraduate Honors Research in Biomedical Engineering	1-5
ECE 4620	Introduction to BioMEMS	3

Biomechanics Track (3 Requisites, 6 Electives)		**24**
MAE 2600	Dynamics	3
MATH 4300	Numerical Analysis	3
BME 4370	Orthopaedic Biomechanics	3
Track Electives		
BME 3075	Introduction to Materials Engineering	3
BME 3170	Biomaterials	3
BME 4003	Design and Development of Biomedical Innovation	3
BIOL_EN 4070	Bioelectricity	3
BME 4085	Problems in Biomedical Engineering	1-5
BME 4170	Biomaterials Interfaces of Implantable Devices	3
BME 4375	Human Movement Biomechanics	3
BME 4470	Biomolecular Engineering and Nanbiotechnology	3
or BME 4470H	Biomolecular Engineering and Nanobiotechnology - Honors	
BME 4480	Physics and Chemistry of Materials	3
BME 4940	Engineering Internship	1-3
BME 4970	Nuclear Magnetic Resonance and Magnetic Resonance Imaging	3
BME 4985	Bioengineering Design II	1-5

BME 4990	Undergraduate Research in Biomedical Engineering	1-6
BME 4995H	Undergraduate Honors Research in Biomedical Engineering	1-5
Biomaterials Track (3 Requisites, 5 Electives)		**24**
BME 3075	Introduction to Materials Engineering	3
BME 3170	Biomaterials	3
BME 4480	Physics and Chemistry of Materials	3
Track Electives		
BME 4003	Design and Development of Biomedical Innovation	3
BIOL_EN 4070	Bioelectricity	3
BME 4075	Brain Signals and Brain Machine Interfaces	3
BME 4085	Problems in Biomedical Engineering	1-5
BME 4170	Biomaterials Interfaces of Implantable Devices	3
BIOL_EN 4231	Transport Phenomena in Materials Processing	3
BME 4360	Biomanufacturing Technologies	3
BME 4370	Orthopaedic Biomechanics	3
BME 4470	Biomolecular Engineering and Nanbiotechnology	3
or BME 4470H	Biomolecular Engineering and Nanobiotechnology - Honors	
BME 4770	Biomedical Optics	3
BME 4940	Engineering Internship	1-3
BME 4970	Nuclear Magnetic Resonance and Magnetic Resonance Imaging	3
BME 4985	Bioengineering Design II	1-5
BME 4990	Undergraduate Research in Biomedical Engineering	1-6
BME 4995H	Undergraduate Honors Research in Biomedical Engineering	1-5
CH_ENG 3262	Chemical Engineering Thermodynamics II	3
CH_ENG 4319	Introduction to Polymers	3

Approved Electives

Cultural Awareness Course Approved List		**3**
Economics Approved List		
ECONOM 1014	Principles of Microeconomics	3
or ECONOM 1014H	Principles of Microeconomics-Honors	
NOTE: ECONOM 1014H fulfills the requirement of a cultural awareness course.		
ECONOM 1015	Principles of Macroeconomics	3
or ECONOM 1015H	Principles of Macroeconomics - Honors	
ECONOM 1051H	General Economics - Honors	5
ABM 1041	Applied Microeconomics	3
ABM 1042	Applied Macroeconomics	3
IMSE 2710		3
History Approved List		
HIST 1100	Survey of American History to 1865	3
or HIST 1100H	Survey of American History to 1865 - Honors	
HIST 1200	Survey of American History Since 1865	3
or HIST 1200H	Survey of American History Since 1865 - Honors	
HIST 1400	American History	5
HIST 2210	Twentieth Century America	3
HIST 2440	History of Missouri	3
or HIST 2440H	History of Missouri - Honors	
HIST 4000	Age of Jefferson	3
HIST 4220	U.S. Society Between the Wars 1918-1945	3
HIST 4230	Our Times: United States Since 1945	3
POL_SC 1100	American Government	3
or POL_SC 1100H	American Government - Honors	
POL_SC 2100	State Government	3
Ethics Approved List		
PHIL 2440	Medical Ethics (recommended)	3
PHIL 1150	Introductory Bioethics	3
CDS 4480	Clinical Ethics	3
or CDS 4480W	Clinical Ethics - Writing Intensive	
NOTE: CDS 4480(W) fulfills both the ethics requirement and the writing intensive designation requirement, but does not count as a H/FA elective.		
Cell and Molecular Biology Approved List		
BME 2070	Cell and Molecular Biology for Engineers	4
BIO_SC 2300	Introduction to Cell Biology	4
Physiology Approved List		
MPP 3202	Elements of Physiology	5
MPP 3550	Physiology for Engineers	3
BIO_SC 3700	Human Physiology	5
Engineering Graphics Approved List		
MAE 1100	Introduction to Computer Aided Design	3
or MAE 1100H	Introduction to Computer Aided Design - Honors	
ENGINR 1100	Engineering Graphics Fundamentals	2
or ENGINR 1100H	Engineering Graphics Fundamentals - Honors	
ENGINR 1110	Solid Modeling for Engineering Design	1
NOTE: If ENGINR 1100 or 1100H is taken, then ENGINR 1110 must also be taken.		
Fluid Mechanics Approved List		
BME 3070	Biological Fluid Mechanics	3
CV_ENG 3700	Fluid Mechanics	3
MAE 3400	Fluid Mechanics	3
Thermodynamics Approved List		
ENGINR 2300	Engineering Thermodynamics	3
CH_ENG 3261	Chemical Engineering Thermodynamics I	3

Accelerated BS to MS in Biological Engineering

The accelerated option will allow students to earn a BS in Biomedical Engineering and an MS in Biological Engineering within five years. Eligible students who have completed at least 90 credit hours with a cumulative GPA of 3.0 and higher. The academic requirements of the accelerated MS program will require a total of 30 credit hours to graduate. Accepted undergraduate students can take 12 hours of graduate level courses that will count toward both the undergraduate and the graduate degrees. Once the student has completed 127 credit hours, the corresponding bachelor's degree will be conferred and they will become graduate students in our MS programs to complete the remaining 18 hours of graduate credit. A minimum of 15 credit hours must be from courses at the 8000 level or above.

Total credits required for graduation must be at least 138 total credit hours:

- Total undergraduate credit hours: 127
- Total dual enrollment credit hours: 12
- Total graduate credit hours: 30

First Year (as Provisional Graduate Student)		**12**
7000+ level BE tech electives		9
7000+ level statistics course		3
Second Year (as Graduate Student)		**18**
Thesis Option		
BIOL_EN 8402	Research Methods	2
BIOL_EN 8087	Seminar in Biological Engineering	1
BIOL_EN 8180	Numerical Methods in Engineering Research	3
8000+ level BE electives		6
BIOL_EN 8990	Masters Thesis Research in Biological Engineering	6
Non Thesis Option		
7000+ level course		3
BIOL_EN 8180	Numerical Methods in Engineering Research	3
8000+ level BE electives		9
BIOL_EN 8085	Problems in Biological Engineering	3

1. At least 15 hours must be from 8000 level and above. Coursework has to be from at least two different proficiency areas.

Proficiency Areas

A student needs to take at least one course from a minimum of two different areas.

Bioprocess Engineering		
BIOL_EN 7001	Topics in Biological Engineering	1-3
BIOL_EN 7160	Food Process Engineering	3
BIOL_EN 7315	Introduction to Bioprocess Engineering	3
BIOL_EN 7316	Biomass Refinery Operation	3
BIOL_EN 8001	Advanced Topics in Biological Engineering (Topic: Advanced Bioprocessing & Biocatalyst)	1-3
BIOL_EN 8280	Advanced Biological Transport Processes	3
Bioenvironmental Engineering		
BIOL_EN 7150	Soil and Water Conservation Engineering	3
BIOL_EN 7250	Irrigation and Drainage Engineering	3
BIOL_EN 7350	Watershed Modeling Using GIS	3
BIOL_EN 7450	Environmental Hydrology	3
BIOL_EN 7560	Observing the Earth from Space	3
BIOL_EN 8250	Water Management Theory	3
Bioelectronics and Instrumentation		
BIOL_EN 7070	Bioelectricity	3
BIOL_EN 7075	Brain Signals and Brain Machine Interfaces	3
BIOL_EN 7310	Feedback Control Systems	3
BIOL_EN 7380	Applied Electronic Instrumentation	4
BIOL_EN 7540	Neural Models and Machine Learning	3
BIOL_EN 7590	Computational Neuroscience	4
BIOL_EN 8380	Modeling and Identification of Engineering Systems	3
Biomaterials		
BIOL_EN 7170	Biomaterials Interfaces of Implantable Devices	3
BIOL_EN 7370	Orthopaedic Biomechanics	3
BIOL_EN 7480	Physics and Chemistry of Materials	3
BIOL_EN 8001	Advanced Topics in Biological Engineering (Topic: Tissue Engineering)	1-3
BIOL_EN 8370	Materials Characterization Techniques	3
BIOL_EN 8670	Orthopaedic Failure Modes and Effect Analysis	3
BIOL_EN 8870	Molecular and Cell Mechanics	3
Biomedical Innovation		
BIOL_EN 8000	Scientific Discovery Leading to Life Science Innovations	3
BIOL_EN 8004	Regulatory Issues in Clinical Research and Clinical Trials	3
BIOL_EN 8100	Design and Development of Biomedical Innovations	3
BIOL_EN 8200	Commercialization of Life Science Innovations	3
Biophotonics and Bioimaging		
BIOL_EN 7420	Introduction to Biomedical Imaging	3
BIOL_EN 7570	Fluorescent Imaging	3
BIOL_EN 7770	Biomedical Optics	3
BIOL_EN 7970	Nuclear Magnetic Resonance and Magnetic Resonance Imaging	3
BIOL_EN 8270	Principles and Applications of Fluorescence	3
BIOL_EN 8570	Microscopic Imaging	3
BIOL_EN 8970	Nuclear Magnetic Resonance and Magnetic Resonance Imaging	3
Biosensing		
BIOL_EN 7470	Biomolecular Engineering and Nanobiotechnology	3
BIOL_EN 7670	Photonics and Nanotechnologies in Optical Biosensors	3
BIOL_EN 7001	Topics in Biological Engineering (Topic: Wearable Biomedical Devices)	1-3
BIOL_EN 8001	Advanced Topics in Biological Engineering (Topic: Bioelectronics & Biosensors)	1-3
BIOL_EN 8170	Sensors and Biosensors	3
BIOL_EN 8470	Ultrasensitive Biodetection	3

Thesis/Non-Thesis Options

All MS students must complete an independent research project supervised by their faculty advisors. Students can choose a thesis (MST) or non-thesis (MSNT) option to complete the masters degree. Both require a total of 30 graduate credit hours and a research project. MST students can take 6 to 12 credit hours of masters research and are required to complete a masters thesis conforming to the Graduate School thesis specifications. MSNT students must take a minimum of 27 credit hours of graduate courses, excluding research and problems courses, and complete a project report approved by the examination committee. During their last semester in the program, students must defend their

thesis or project report in front of an examination committee composed of their graduate advisor and at least two other faculty members.

Semester Plan

Below is a sample plan of study, semester by semester. A student's actual plan may vary based on course choices where options are available.

First Year			
Fall	**CR**	**Spring**	**CR**
ENGINR 1000	1	ENGINR 1050	2
MATH 1500	5	MATH 1700	5
ENGLSH 1000	3	PHYSCS 2750	5
CHEM 1400 & CHEM 1401	4	BIO_SC 1500	5
BS/SS Economics from approved list	3		
	16		**17**
Second Year			
Fall	**CR**	**Spring**	**CR**
BME 2080	3	BME 2180	3
MATH 2300	3	MATH 4100	3
PHYSCS 2760	5	ENGINR 1200	3
CHEM 2100	3	BME 2000	2
Engineering Graphics from approved list	3	BME 2070	4
	17		**15**
Third Year			
Fall	**CR**	**Spring**	**CR**
BME 3180	3	BME 4380	4
ENGINR 2200	3	Track Requiste or Elective	3
ENGINR 2300	3	STAT 4710	3
Fluid Mechanics from approved list	3	BS/SS US Government or History Elective	3
Track Requisite or Elective	3	H/FA Ethics Elective	3
BS/SS Elective	3		
	18		**16**
Fourth Year			
Fall	**CR**	**Spring**	**CR**
BME 4980W	3	Track Requisite or Elective	3
Physiology from approved list	3	Track Requisite or Elective	3
Track Requisite or Elective	3	Track Requisite or Elective	3
Track Requisite or Elective	3	Track Requisite or Elective	3
H/FA Elective	3	H/FA Elective	3
	15		**15**

Total Credits: 129