BIOMEDICAL ENGINEERING, BSE

More Information: https://engineering.case.edu/ebme/
Degree: Bachelor of Science in Engineering (BSE)
Major: Biomedical Engineering

Program Overview

The Case Western Reserve undergraduate program leading to the Bachelor of Science in Engineering degree program with a major in Biomedical Engineering was established in 1972 and has been accredited since its inception.

Some BSE graduates are employed in industry and medical centers. Others continue graduate or professional studies in biomedical engineering and other fields. Students with strong quantitative skills and an interest in medicine may consider the undergraduate biomedical engineering program as an exciting alternative to conventional premedical programs. In addition to the University general education requirements, the undergraduate program has three major components: (1) Engineering Core, (2) BME Core, and (3) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

- BME Specialty Tracks. The Engineering Core provides a fundamental background in mathematics, physics, chemistry, and engineering. The BME Core provides fundamentals in biology and integrates engineering with biomedical science to solve medical problems. Hands-on experience in BME is developed through undergraduate laboratory and project courses. In addition, by choosing a BME Track, the student can study a specific area of interest in depth. Appropriate choice of elective courses can lead to a minor in a related engineering discipline without taking extra classes beyond those needed for the BME major. This integrated program is designed to ensure that BME graduates are competent engineers with credentials that are well recognized by potential employers.

The Bachelor of Science in Engineering degree program in Biomedical Engineering is accredited by the Engineering Accreditation Commission of ABET, under the commission's General Criteria and Program Criteria for Biomedical Engineering.

Program Educational Objectives

At the undergraduate level, we direct our efforts toward two educational objectives that describe the performance of alumni 3-6 years after graduation.

a. Our graduates will successfully enter and complete post-baccalaureate advanced degree programs, including those in biomedical engineering.
b. Our graduates will obtain jobs in the biomedical arena and advance to positions of greater responsibility.

Learning Outcomes

As preparation for achieving the above educational objectives, the Bachelor of Science in Engineering with a major in Biomedical Engineering is designed so that students attain:

- An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- An ability to communicate effectively with a range of audiences
- An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Co-op and Internship Programs

Opportunities are available for students to alternate studies with work in industry or government as a co-op student, which involves paid full-time employment over seven months (one semester and one summer). Students may work in one or two co-ops, beginning in the third year of study. Co-ops provide students the opportunity to gain valuable hands-on experience in their field by completing a significant engineering project while receiving professional mentoring. During a co-op placement, students do not pay tuition but maintain their full-time student status while earning a salary. Alternatively or additionally, students may obtain employment as summer interns.

Undergraduate Policies

For undergraduate policies and procedures, please review the Undergraduate Academics section of the General Bulletin.

Accelerated Master's Programs

Undergraduate students may participate in accelerated programs toward graduate or professional degrees. For more information and details of the policies and procedures related to accelerated studies, please visit the Undergraduate Academics section of the General Bulletin.

Additional information for BME students:

a. An eligible BME faculty member (primary or secondary) must agree to serve as the MS research advisor and a primary BME faculty member (who might be the same person as the research advisor) must agree to be the academic advisor. *Obtaining this agreement is the responsibility of the applying student.* The BS/MS application must include letters of recommendation from both the research and academic advisor that states that they agree to serve in these roles and that they support the BS/MS application.

b. The BME department does not guarantee financial support during the MS portion of this program. However, the GEC requires students and potential research advisors to discuss and agree to some financial arrangement. *The letter of recommendation from the proposed research advisor must, therefore, indicate that the issue of financial support has*

been discussed and that some arrangement has been agreed upon. The details of this arrangement do not need to be included in the letter.

c. Complete a standard application to the School of Graduate Studies via the online application system.

d. Complete the BS/MS Planned Program of Study (PPOS) form. Make sure to check the "BS/MS" box and to indicate which courses are to be double-counted (by checking the "double count" box next to the relevant courses on the POS).

e. Obtain an approval signature from the Office of Undergraduate Studies on the proposed POS prior to submitting the package (below) to the department.

f. Prepare the application package that includes the following:

- A current transcript
- The proposed MS Program of Study. Make sure that the Program of Study specifies both the academic and research advisors *and includes both of their signatures*. This form also needs to indicate the courses that are intended to be "double counted".
  - Only graduate-level courses (400-or higher) can be double counted. This typically means that students should register for 400-level courses to satisfy undergraduate technical electives.
  - It is possible to "double count" 3 credit hours of EBME 398. To do this, 3 credit hours of EBME 651 (Thesis-Focused Track) or EBME 695 (Project-Focused Track) should replace EBME 398 in the fall or spring of the senior year. You should register for EBME 651 or EBME 695 (but NOT EBME 398). However, you must attend the meetings of EBME 398 and also fulfill all of the course requirements for EBME 398.
  - A maximum of 9 credit hours can be double counted. Typically, these are two 3 credit hours courses (400-level or high) and 3 credit hours of EBME 651 or EBME 695 (in place of EBME 398).
- Three reference reports (in sealed envelopes), including letters from your proposed academic and research advisor(s).

g. Submit the proposed POS, transcript, and letters of recommendation to the BME Graduate Coordinator.

No admission decision will be made until the POS is approved by the GEC. After a positive recommendation by the GEC, a letter of conditional admission will be sent. The condition for admission is the submission of GRE scores within two months of completing the BS requirements. The student cannot graduate from the BS/MS program without official GRE scores. This is a BME requirement and not a CSE requirement. Note that it is strongly recommended that students plan to take the GRE exam in the Fall semester of their senior year to be eligible for pre-doctoral fellowships from the National Science Foundation or other sources.

Program Requirements

Students seeking to complete this major and degree program must meet the general requirements for bachelor's degrees and the Unified General Education Requirements. Students completing this program as a secondary major while completing another undergraduate degree program do not need to satisfy the school-specific requirements associated with this major.

Code	Title	Credit Hours
Required Mathematics, Science and Engineering Courses		
MATH 121	Calculus for Science and Engineering I	4
MATH 122	Calculus for Science and Engineering II	4
or MATH 124	Calculus II	
MATH 223	Calculus for Science and Engineering III	3
or MATH 227	Calculus III	
MATH 224	Elementary Differential Equations	3
or MATH 228	Differential Equations	
PHYS 121	General Physics I - Mechanics	4
or PHYS 123	Physics and Frontiers I - Mechanics	
PHYS 122	General Physics II - Electricity and Magnetism	4
or PHYS 124	Physics and Frontiers II - Electricity and Magnetism	
CHEM 111	Principles of Chemistry for Engineers	4
ENGR 130	Foundations of Engineering and Programming [a]	3
ENGR 145	Chemistry of Materials	4
ENGR 200	Statics and Strength of Materials	3
ENGR 210	Introduction to Circuits and Instrumentation	4
ENGR 225	[b]	4
ENGR 399	Impact of Engineering on Society	3

a Students pursuing the Biomedical Computing & Analysis concentration may substitute CSDS 132 for ENGR 130.

b Students pursuing the Biomaterials concentration may substitute EMAC 351 and EMAC 352 for ENGR 225.

Code	Title	Credit Hours
Required Biomedical Engineering Courses		
EBME 201	Physiology-Biophysics I	3
EBME 202	Physiology-Biophysics II	3
EBME 306 & EBME 356	Introduction to Biomedical Materials and Introduction to Biomaterials Engineering - Laboratory	4
EBME 308 & EBME 358	Biomedical Signals and Systems and Biomedical Signals and Systems Laboratory	4
EBME 309 & EBME 359	Modeling of Biomedical Systems and Biomedical Computer Simulation Laboratory	4
EBME 310 & EBME 360	Principles of Biomedical Instrumentation and Biomedical Instrumentation Laboratory	4
EBME 370	Principles of Biomedical Engineering Design	3
EBME 380	Biomedical Engineering Design Experience	3
Engineering, Mathematics or Natural Science Elective		3
Eight Concentration Electives		24-26
Total Credit Hours		**55-57**

Natural Sciences, Mathematics or Statistics Elective

Candidates for the Bachelor of Science in Engineering degree must fulfill a Natural Sciences, Mathematics or Statistics requirement as part of the Engineering Core, which is designated by the major department. Note that this is distinct from the engineering, mathematics or natural science elective required by the BME major and mentioned above. Biomedical Engineering majors may meet this requirement by taking one of the following statistics courses:

Code	Title	Credit Hours
STAT 312	Basic Statistics for Engineering and Science [a]	3
STAT 313	Statistics for Experimenters	3
STAT 332	Statistics for Signal Processing	3
STAT 333	Uncertainty in Engineering and Science	3

a Students pursuing the Biomedical Computing and Analysis concentration need to take STAT 312R as a pre-req to DSCI 351.

Concentration Requirements

Biomedical Engineering Concentrations

Majors in Biomedical Engineering choose a concentration, with specific courses.

Required courses for these tracks are presented in the tables below. These concentrations provide the student with a solid background in a well-defined area of biomedical engineering. To meet specific educational needs, students may choose alternatives from among the suggested electives or design unique specialties. These options are flexible and subject to departmental guidelines and faculty approval.

Approval of technical electives (TE): Pre-approved TE (listed below) need no further approval. 300-400 level courses offered by a department in the Case School of Engineering may be approved as a TE by a student's academic advisor. Any other course must be approved by petition to the BME Undergraduate Education Committee. Transfer and study abroad courses must be approved by the BME Program Academic Representative. In all cases, courses should be chosen as TE's that are consistent with the track and are consistent with student's career plans. Students are encouraged to choose electives that form a thematic depth.

Biomedical Devices and Instrumentation Concentration

Code	Title	Credit Hours
Required Courses:		
ECSE 245	Electronic Circuits	4
ECSE 281	Logic Design and Computer Organization	4
ECSE 309	Electromagnetic Fields I	3
Technical Elective		3-4
Technical Elective		3-4
Technical Elective		3-4
Conjoiner course		**3**
Choose one of the following:		
EBME 320	Biomedical Imaging	
or EBME 327	Bioelectric Engineering	
Total Credit Hours		**24-26**

Biomedical Devices and Instrumentation Concentration Technical Electives

Code	Title	Credit Hours
Electronics:		
ECSE 321	Semiconductor Electronic Devices	4
ECSE 322	Integrated Circuits and Electronic Devices	3
ECSE 344	Electronic Analysis and Design	3
ECSE 371	Applied Circuit Design	4
Software:		
CSDS 233	Introduction to Data Structures	4
CSDS 310	Algorithms	3
CSDS 337	Compiler Design	4
CSDS 338	Intro to Operating Systems and Concurrent Programming	4
ECSE 313	Signal Processing	3
ECSE 351	Communications and Signal Analysis	3
ECSE 354	Digital Communications	3
Modeling/Simulation:		
ECSE 324	Modeling and Simulation of Continuous Dynamical Systems	3
ECSE 346	Engineering Optimization	3
EBME 478	Computational Neuroscience	3
Other:		
EBME 307	Biomechanical Prosthetic Systems	3
EBME 320	Biomedical Imaging	3
EBME 401D	Biomedical Instrumentation and Signal Processing	3
EBME 407	Neural Interfacing	3
EBME 421	Bioelectric Phenomena	3
ECSE 304	Control Engineering I with Laboratory	3
CSDS 313	Introduction to Data Analysis	3
CSDS 341	Introduction to Database Systems	3

Biomaterials Concentration

Code	Title	Credit Hours
Required Courses:		
CHEM 223	Introductory Organic Chemistry I	3
EMAC 270	Introduction to Polymer Science and Engineering	3
EMAC 351	Physical Chemistry for Engineering	3
EMAC 352	Polymer Physics and Engineering	3
Technical Elective		3-4
Technical Elective		3-4
Technical Elective		3-4
Conjoiner course		**3**
Choose one of the following:		
EBME 316	Biomaterials for Drug Delivery	
or EBME 325	Introduction to Tissue Engineering	
or EBME 305	Materials for Prosthetics and Orthotics	
Total Credit Hours		**24-27**

Biomaterials Concentration Technical Electives

Code	Title	Credit Hours
EBME/EMAC 303	Structure of Biological Materials	3
EBME 305	Materials for Prosthetics and Orthotics	3
EBME 316/416	Biomaterials for Drug Delivery	3
EBME 325	Introduction to Tissue Engineering	3
EBME 350	Quantitative Molecular, Cellular and Tissue Bioengineering	3
EBME 406/ EMAC 471	Polymers in Medicine	3
EBME 426	Nanomedicine	3

ECHE 355	Quantitative Molecular, Cellular and Tissue Bioengineering	3
ECHE 340	Biochemical Engineering	3
ECHE 360	Transport Phenomena for Chemical Systems	4
ECHE 364	Chemical Reaction Processes	4
ECHE 386	Protein Engineering	3
ECHE 474	Biotransport Processes	3
EMAC 276	Polymer Properties and Design	3
EMAC 355	Polymer Analysis Laboratory	3
EMAC 370	Polymer Chemistry	3
EMAC 376/476	Polymer Engineering	3
EMAC 377	Polymer Processing	3
EMAE 160	Mechanical Manufacturing	3
EMSE 220	Materials Laboratory I	2
EMSE 276	Materials Properties: Composition and Structure	3
EMSE 327	Thermodynamic Stability and Rate Processes	3
EMSE 335	Strategic Metals and Materials for the 21st Century	3
EMSE 345	Engineered Materials for Biomedical Applications	3
EMSE 372	Structural Materials by Design	4
EMSE 435	Strategic Metals and Materials for the 21st Century	3

Biomechanics Concentration

Code	Title	Credit Hours
Required Courses:		
EMAE 160	Mechanical Manufacturing	3
EMAE 181	Dynamics	3
ECIV 310	Strength of Materials	3
EMAE 260	Design and Manufacturing I	3
Technical Elective		3-4
Technical Elective		3-4
Technical Elective		3-4
Conjoiner course		**3**
Choose one of the following:		
EMAE 414	Nanobiomechanics in Biology	
or EBME 307	Biomechanical Prosthetic Systems	
Total Credit Hours		**24-27**

Biomechanics Concentration Technical Electives

Code	Title	Credit Hours
EBME 305	Materials for Prosthetics and Orthotics	3
EBME 329	Tissue Biomechanics	3
EBME 398	Biomedical Engineering Research Experience I [a]	1 - 3
ECIV 420	Finite Element Analysis	3
EMAE 250	Computers in Mechanical Engineering	3
EMAE 290	Computer-Aided Manufacturing	3
EMAE 307	Fundamentals of Biomechanics	3
EMAE 350	Mechanical Engineering Analysis	3
EMAE 370	Design of Mechanical Elements	3
EMAE 390	Advanced Manufacturing Technology	3
EMAE 372	Structural Materials by Design	4
EMAE 415	Introduction to Musculo-skeletal Biomechanics	3
EMSE 372	Structural Materials by Design	4

a Requires additional approval

Biomedical Computing and Analysis Concentration

Code	Title	Credit Hours
Required Courses:		
CSDS 233	Introduction to Data Structures	4
CSDS 302	Discrete Mathematics	3
CSDS 310	Algorithms	3
DSCI 351/451	Exploratory Data Science	3
Technical Elective		3-4
Technical Elective		3-4
Technical Elective		3-4
Conjoiner course		**3**
Choose one of the following:		
EBME 320	Biomedical Imaging	
or EBME 327	Bioelectric Engineering	
or EBME 361	Biomedical Image Processing and Analysis	
Total Credit Hours		**25-28**

Biomedical Computing and Analysis Concentration Technical Electives

Code	Title	Credit Hours
CSDS 391	Introduction to Artificial Intelligence	3
EBME 300	Dynamics of Biological Systems: A Quantitative Introduction to Biology	3
EBME 398	Biomedical Engineering Research Experience I	1 - 3
ECSE 304	Control Engineering I with Laboratory	3
ECSE 346	Engineering Optimization	3
ECSE 350	Operations and Systems Design	3
ECSE 352	Engineering Economics and Decision Analysis	3
CSDS 293	Software Craftsmanship	4
CSDS 310	Algorithms	3
CSDS 338	Intro to Operating Systems and Concurrent Programming	4
CSDS 341N	Introduction to Database Systems	3
CSDS 343	Theoretical Computer Science	3
CSDS 391	Introduction to Artificial Intelligence	3
CSDS 394	Introduction to Information Theory	3
EBME 398	Biomedical Engineering Research Experience I	1 - 3
ECSE 281	Logic Design and Computer Organization	4
ECSE 313	Signal Processing	3

Sample Plan of Study

The following is an example program of study. Variations depend on advanced placements. Students should work with their advisors to map out an individual plan of study. Concentration-specific example program-of-study templates are linked above.

First Year		
Fall		**Credit Hours**
EBME 105	Introduction to Biomedical Engineering	3
CHEM 111	Principles of Chemistry for Engineers	4
MATH 121	Calculus for Science and Engineering I	4
Academic Inquiry Seminar, Breadth, or Elective course [a]		3
ENGR 130	Foundations of Engineering and Programming [b]	3
	Credit Hours	**17**
Spring		
ENGR 145	Chemistry of Materials	4
MATH 122	Calculus for Science and Engineering II	4
PHYS 121	General Physics I - Mechanics	4
Academic Inquiry Seminar, Breadth, or Elective course [a]		3
	Credit Hours	**15**
Second Year		
Fall		
EBME 201	Physiology-Biophysics I	3
MATH 223	Calculus for Science and Engineering III	3
PHYS 122	General Physics II - Electricity and Magnetism	4
ENGR 225		4
Breadth, or Elective course [a]		3
	Credit Hours	**17**
Spring		
EBME 202	Physiology-Biophysics II	3
ENGR 210	Introduction to Circuits and Instrumentation	4
MATH 224	Elementary Differential Equations	3
Breadth, or Elective course [a]		3
Concentration Elective or Science Elective		3
	Credit Hours	**16**
Third Year		
Fall		
EBME 306 & EBME 356	Introduction to Biomedical Materials and Introduction to Biomaterials Engineering - Laboratory	4
EBME 308 & EBME 358	Biomedical Signals and Systems and Biomedical Signals and Systems Laboratory	4
ENGR 399	Impact of Engineering on Society	3
Breadth, or Elective course [a]		3
Concentration Elective		3
	Credit Hours	**17**
Spring		
EBME 310 & EBME 360	Principles of Biomedical Instrumentation and Biomedical Instrumentation Laboratory	4
ENGR 200	Statics and Strength of Materials	3
EBME 309 & EBME 359	Modeling of Biomedical Systems and Biomedical Computer Simulation Laboratory	4
Breadth, or Elective course [a]		3
Concentration Elective		3
	Credit Hours	**17**
Fourth Year		
Fall		
EBME 370	Principles of Biomedical Engineering Design	3
Breadth, or Elective course [a]		3
Mathematics/Science/Engineering Elective		3
Natural Sciences/Mathematics/Statistics Elective		3
Concentration Elective		3
Concentration Elective		3
	Credit Hours	**18**
Spring		
EBME 380	Biomedical Engineering Design Experience	3
Breadth, or Elective course [a]		3
Concentration Elective		3
Concentration Elective		3
Concentration Elective		3
	Credit Hours	**15**
	Total Credit Hours	**132**

a Unified General Education Requirement.

b Students pursuing the Biomedical Computing & Analysis concentration may substitute CSDS 132 for ENGR 130.