# BIOMEDICAL ENGINEERING

Biomedical engineering is an exciting, multidisciplinary field that lies at the interface of medicine, biology and engineering. Biomedical engineers use engineering principles to analyze and solve problems in biology and medicine, providing an overall enhancement to healthcare. Biomedical engineers create technology to save lives and improve the quality of life. Much of the equipment in hospitals and clinics across the globe was designed, built and tested by biomedical engineers. At the same time, biomedical engineers employ concepts learned from biology and medicine to generate new (biomimetic) engineering designs in fields such as robotics and artificial intelligence.

**Course code for this program is BMEN.**

## Bachelor's Degree

- Biomedical Engineering - Bachelor of Science (BSBM) (https://catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/biomedical-engineering/biomedical-engineering-bachelor-science-bsbm/)

## Minor

- Biomedical Engineering - Minor (https://catalog.colorado.edu/undergraduate/colleges-schools/engineering-applied-science/programs-study/biomedical-engineering/biomedical-engineering-minor/)

## Faculty

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

Ahmed, Alaa A. (https://experts.colorado.edu/display/fisid_144736/)
Assistant Professor; PhD, University of Michigan

Alistar, Mirela (https://experts.colorado.edu/display/fisid_164177/)
Assistant Professor; PhD, Technical University of Denmark

Allen, Mary Ann (https://experts.colorado.edu/display/fisid_149077/)
Research Associate Professor; PhD, University of Colorado Boulder

Borden, Mark A. (https://experts.colorado.edu/display/fisid_148514/)
Associate Professor; PhD, University of California, Davis

Bottenus, Nick (https://experts.colorado.edu/individual/fisid_165371/)
Assistant Professor; PhD, Duke University

Bruns, Carson J. (https://experts.colorado.edu/display/fisid_159851/)
Assistant Professor; PhD, Northwestern University

Calve, Sarah (https://experts.colorado.edu/individual/fisid_165779/)
Associate Professor; PhD, University of Michigan

Cha, Jennifer N. (https://experts.colorado.edu/display/fisid_151746/)
Professor; PhD, University of California, Santa Barbara

Clark, Torin K. (https://experts.colorado.edu/display/fisid_155959/)
Assistant Professor; PhD, Massachusetts Institute of Technology

Davis, Robert H. (https://experts.colorado.edu/individual/fisid_113653/)
Associate Faculty Director; PhD, Stanford University

Del Rio Flores, Antonio
Assistant Professor; PhD, University of California, Berkeley

Ding, Xiaoyun (https://experts.colorado.edu/display/fisid_158563/)
Assistant Professor; PhD, Pennsylvania State University

Dowell, Robin D. (https://experts.colorado.edu/display/fisid_147779/)
Professor; DSc, Washington University

Enoka, Roger M. (https://experts.colorado.edu/display/fisid_110122/)
Professor; PhD, University of Washington

Ferguson, Virginia L. (https://experts.colorado.edu/display/fisid_110131/)
Associate Professor; PhD, University of Colorado Boulder

Fox, Jerome Michael (https://experts.colorado.edu/display/fisid_156682/)
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Gopinath, Juliet T. (https://experts.colorado.edu/display/fisid_147075/)
Associate Professor; PhD, Massachusetts Institute of Technology

Grabowski, Alena Marie (https://experts.colorado.edu/display/fisid_149727/)
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Hayman, Allison P. (https://experts.colorado.edu/display/fisid_156275/)
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Professor; PhD, University of California, Berkeley

Hind, Laurel (https://experts.colorado.edu/individual/fisid_165642/)
Assistant Professor; PhD, University of Pennsylvania

Huang, Shu-Wei (https://experts.colorado.edu/display/fisid_159847/)
Assistant Professor; PhD, MIT, Cambridge

Layer, Ryan M. (https://experts.colorado.edu/display/fisid_163567/)
Assistant Professor; PhD, University of Virginia

Li, Jun
Assistant Professor; PhD, University of Wisconsin-Madison

Long, James (https://experts.colorado.edu/display/fisid_177126/)
Teaching Assistant Professor; PhD, Duke University

Lynch, Maureen Ellen (https://experts.colorado.edu/display/fisid_163404/)
Assistant Professor; PhD, Cornell University

McLaughin, Jessica (https://experts.colorado.edu/individual/fisid_167401/)
Teaching Assistant Professor; PhD, Northeastern University

McLeod, Robert R. (https://experts.colorado.edu/display/fisid_107547/)
Professor; PhD, University of Colorado Boulder

Mukherjee, Debanjan (https://experts.colorado.edu/individual/fisid_164181/)
Assistant Professor; PhD, University of California, Berkeley

Murray, Todd W. (https://experts.colorado.edu/display/fisid_146549/)
Professor; PhD, Johns Hopkins University

Myers, Chris (https://experts.colorado.edu/display/fisid_167168/)
Professor; PhD, Stanford University

Neu, Corey P. (https://experts.colorado.edu/display/fisid_156210/)
Associate Professor; PhD, University of California, Davis

Park, Won (https://experts.colorado.edu/display/fisid_122676/)
Associate Professor, Associate Chair; PhD, Georgia Institute of Technology

Piestun, Rafael (https://experts.colorado.edu/display/fisid_118538/)
Professor; PhD, Israel Instit of Tech (Israel)

Regueiro, Richard A. (https://experts.colorado.edu/display/fisid_134705/)
Associate Professor; PhD, Stanford University

Rentschler, Mark E. (https://experts.colorado.edu/display/fisid_146091/)
Associate Professor; PhD, University of Nebraska-Lincoln

Sankaranarayanan, Sriram (https://experts.colorado.edu/display/fisid_147413/)
Associate Professor; PhD, Stanford University

Shields, C. Wyatt IV (https://experts.colorado.edu/individual/fisid_165173/)
Assistant Professor; PhD, Duke University

Spencer, Sabrina Leigh (https://experts.colorado.edu/display/fisid_154911/)
Associate Professor; PhD, Massachusetts Institute of Technology

Sprenger, Kayla (https://experts.colorado.edu/individual/fisid_165650/)
Assistant Professor; PhD, University of Washington

Tan, Wei (https://experts.colorado.edu/display/fisid_141464/)
Associate Professor; PhD, University of Illinois at Chicago

Vernerey, Franck J. (https://experts.colorado.edu/display/fisid_144760/)
Professor; PhD, Northwestern University

Welker, Cara (https://experts.colorado.edu/display/fisid_168549/)
Assistant Professor; Ph.D., Stanford University

Xu, Nicole (https://experts.colorado.edu/display/fisid_172095/)
Assistant Professor; PhD, Stanford University

Yeh, Tom (https://experts.colorado.edu/display/fisid_151584/)
Associate Professor; PhD, Massachusetts Institute of Technology

Zhang, Yide
Assistant Professor; PhD, University of Notre Dame

# Courses

**BMEN 1000 (1) Exploring Biomedical Engineering**
Introduces the biomedical engineering profession, curriculum, career pathways, ethics and responsibilities, and research opportunities. Academic and industry speakers are invited to address various biomedical engineering topics.
**Requisites:** Restricted to Biomedical Engineering (BMEN), Open Option Engineering (XXEN) majors and IUT on track applicants.

**BMEN 1020 (3) Computer-Aided Design for Biomedical Engineers**
Introduces engineering drawing techniques through modern computer aided design (CAD) software. The course will begin with an introduction of spatial visualization skills, and then an in-depth introduction to Solidworks, an industry standard CAD software tool. Additional topics include geometric design and tolerancing techniques and design for manufacturing. Students taking this course for the BME major will need to take BMEN 1035 to meet the Fabrication requirement.
**Equivalent - Duplicate Degree Credit Not Granted:** GEEN 1017 and MCEN 1026

**BMEN 1025 (4) Computer-Aided Design & Fabrication**
Introduces engineering drawing techniques through modern computer aided design (CAD) software, and fabrication of some of these designs. The course will begin with an introduction of spatial visualization skills, then an in-depth introduction to Solidworks, an industry standard CAD software tool, along with introduction to fabrication processes including laser cutting, and 3D printing. Additional topics include geometric design and tolerancing techniques and design for manufacturing.
**Requisites:** Restricted to Biomedical Engineering (BMEN) majors only.

**BMEN 1035 (1) Introduction to Fabrication for Biomedical Engineering**
The purpose of this course is to provide biomedical and other engineering students with an introduction to fabrication processes and rapid prototyping techniques including laser cutting, 3D printing, and 3D scanning. Additional topics include geometric design and tolerancing (GD&T) techniques and design for manufacturing (DFM) methods. Provides additional fabrication experience for students in CEAS who have already taken CAD courses and do not want to duplicate material by taking BMEN 1025.
**Equivalent - Duplicate Degree Credit Not Granted:** the fabrication component of BMEN 1025
**Requisites:** Requires prerequisite course of GEEN 1017 or BMEN 1020 (minimum grade C-). Restricted to Biomedical Engineering (BMEN) majors and IUT on track applicants.

**BMEN 2000 (3) Introduction to Biomedical Engineering**
Reviews concepts from molecular and cellular biology. Establishes important aspects of human physiology and engineering principles to develop a basic understanding of the biomedical engineering field. Introduces topics such as biomechanics, bioinstrumentation, bioimaging and biotechnology.
**Requisites:** Requires prerequisite or co-requisite Biology course MCDB 1150 or BIEN 2810 or EBIO 1210 (min grade C-). Requires prerequisite Chemistry course CHEN 1201 or CHEN 1211 or CHEM 1113 or CHEM 1400 or MCEN 1024 (min grade C-).

**BMEN 2010 (3) Biomaterials**
Introduces the science and engineering of biomaterials, with an emphasis on biomechanical aspects. Addresses the design, fabrication, testing, applications and performance of synthetic and natural materials that are used in a wide variety of biomedical prosthetics, implants and devices. In addition to attending lectures, students will conduct a laboratory experiment and a case study.
**Requisites:** Requires prerequisite course of CHEN 1201 or CHEN 1211 or CHEM 1113 or CHEM 1400 or MCEN 1024 (minimum grade C-). Restricted to Biomedical Engineering (BMEN) majors, minors and IUT on track applicants.
**Recommended:** for students in fourth semester of Biomedical Engineering curriculum or higher.

**BMEN 2100 (3) Biomedical Engineering Principles and Methods**
This course is an introduction to the fundamental principles and mathematical methods of biomedical engineering. Core conservation equations are applied to mass, energy, charge, and momentum transfer in biomedical systems. Additional topics may cover a breadth of exposure in diagnostics and analytical techniques, statistical analysis of biomedical data, bioinformatics, bioinstrumentation.
**Requisites:** Prereq (APPM 1350 or Math 1300 or APPM 1345) and (CHEN 1201 or CHEN 1211 or CHEM 1113 or CHEM 1400 or MCEN 1024) and (PHYS 1110 or PHYS 1115) and (MCDB 1150 or BIEN 2810 or EBIO 1210) (all min C-). Restricted to BMEN majors/min IUT On Track applicants.

**BMEN 3010 (3) Biotransport**
An introduction to the modeling of complex biological systems using principles of transport phenomena and biochemical kinetics. Includes the conservation of mass and momentum; rheology of Newtonian and non-Newtonian fluids; steady and transient diffusion in reacting systems; dimensional analysis; homogeneous versus heterogeneous reaction systems; and physiological transport systems, including receptor-mediated endocytosis and oxygen and drug transport.
**Requisites:** Requires prereq courses BMEN 2100; CHEN 1310 or ASEN 1320 or CSCI 1300 or ECEN 1310; PHYS 1100 or PHYS 1115; and coreq of APPM 2360 or MATH 3430 (min grade C-). Restricted to Biomedical Engineering (BMEN) majors.
**Recommended:** for students in fifth semester of Biomedical Engineering curriculum or higher.

**BMEN 3030 (4) Bioinstrumentation**
This course will provide an overview of instrumentation systems used in clinical medicine and biomedical research. Systems for measuring biologic signals will be discussed including biopotentials, stress and strain, pressure, temperature, and optical properties to interpret data from living systems. There will be applications to engineering design, including a semester-long design project that incorporates the interactions between living and non-living systems. There will also be discussion of ethical and regulatory issues related to bioinstrumentation.
**Requisites:** Requires prerequisite courses of BMEN 2000 or BMEN 2100 and ECEN 2250 (all minimum grade C-). Restricted to Biomedical Engineering (BMEN) major students.
**Recommended:** for students in sixth semester of Biomedical Engineering curriculum or higher.

**BMEN 4010 (3) Biomedical Engineering Capstone Design I**
Offers the first in a two-course sequence of capstone design. Project supervisors and teams are paired through a pitch process, wherein teams pitch their design ideas to meet an existing need on a project. Project is in an area of biomedical engineering, such as biomedical instrumentation, biosensors, tissue engineering, biological signal processing, biological modeling and simulation, clinical imaging or informational systems, etc. Projects will be conducted by teams of typically three to five students, and projects must include significant design experience. The first semester focuses on research of background, planning, crafting of needs statement, and initial work on senior design project . Formal proposal must be approved by technical advisor.
**Requisites:** Prereq of (BMEN 1025 or MCEN 1025) and BMEN 2010 and BMEN 3010. Pre or coreq of ENES 1010 or ENES 3100 or ENLP 3100 or PHYS 3050 or WRTG 3030 or WRTG 3035 (all min. grade C-). Restricted to BMEN majors w 87-180 credits.

**BMEN 4020 (3) Biomedical Engineering Capstone Design II**
Continues BMEN 4010. Teams continue to develop, construct, and evaluate prototypes with consideration of real-world fiscal, regulatory, and safety conditions. Progress is monitored through a series of oral presentations and peer review of teamwork and team dynamics. Requires students to complete a working prototype or simulation as appropriate, and a final written report with oral presentation at the semester Design Expo. Written final report must be approved by the faculty.
**Requisites:** Requires prerequisite course of BMEN 4010 (minimum grade C-). Restricted to Biomedical Engineering (BMEN) majors.

**BMEN 4117 (3) Anatomy and Physiology for Biomedical Engineering**
The main objective of this multidisciplinary course is to explore human physiological function from the viewpoint of an engineer. It provides an introduction to human anatomy and physiology with a focus on learning anatomical structures, biological signaling, physiological and pathological conditions, as well as fundamental biomedical engineering concepts that apply quantitative analyses (mass transfer, fluid dynamics, mechanics, modeling) and engineering concepts (e.g., device design to restore defective physiological functions) to understand physiology and pathology.
**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4117 or MCEN 5117 BMEN 5117
**Requisites:** Requires prerequisite of BMEN 2000 or BMEN 2100 (minimum grade C-). Restricted to Biomedical Engineering (BMEN) and Mechanical Engineering (MCEN) majors.
**Recommended:** Prerequisites BMEN 2010 or BMEN 3010 (all minimum grade C-).

**BMEN 4519 (1-4) Special Topics in Biomedical Engineering**
Credit hours and subject matter to be selected from topics of current interest.
**Repeatable:** Repeatable for up to 15 total credit hours. Allows multiple enrollment in term.
**Requisites:** Restricted to students with 57-180 credits. Biomedical Engineering (BMEN) majors only.

**BMEN 4840 (1-3) Independent Study**
Provides opportunities for independent study at the undergraduate level. Subject and/or project agreed upon by the student and instructor to fit the needs of the student.
**Repeatable:** Repeatable for up to 6 total credit hours. Allows multiple enrollment in term.
**Requisites:** Restricted to Biomedical Engineering (BMEN) majors only.

**BMEN 5117 (3) Anatomy and Physiology for Biomedical Engineering**
The main objective of this multidisciplinary course is to explore human physiological function from the viewpoint of an engineer. It provides an introduction to human anatomy and physiology with a focus on learning anatomical structures, biological signaling, physiological and pathological conditions, as well as fundamental biomedical engineering concepts that apply quantitative analyses (mass transfer, fluid dynamics, mechanics, modeling) and engineering concepts (e.g., device design to restore defective physiological functions) to understand physiology and pathology. Graduate students will be required to present a primary literature review and lead discussion during a class period, as well as take the lead on the final project: a mock NIH grant proposal.
**Equivalent - Duplicate Degree Credit Not Granted:** MCEN 4117 or MCEN 5117 BMEN 4117
**Requisites:** Restricted to graduate Biomedical Engineering students only.

**BMEN 5840 (1-6) Independent Study**
Provides opportunities for independent study at the graduate level. Subject and/or project agreed upon by the student and instructor to fit the needs of the student.
**Repeatable:** Repeatable for up to 30 total credit hours.
**Requisites:** Restricted to graduate Biomedical Engineering students only.

**BMEN 5939 (1-6) Biomedical Engineering Internship**
Grants credit to international graduate students for conducting research via professional research opportunities in the biomedical engineering field. Students are responsible for securing their own internships.
**Repeatable:** Repeatable for up to 6 total credit hours.
**Requisites:** Restricted to graduate students only.

**BMEN 6519 (1-3) Special Topics in Biomedical Engineering**
Credit hours and subject matter to be arranged.
**Repeatable:** Repeatable for up to 12 total credit hours. Allows multiple enrollment in term.

**BMEN 6949 (1) Master's Candidate for Degree**
Credit hours and subject matter to be arranged.

**BMEN 6950 (1-6) Master's Thesis**
Work with a faculty advisor on a masters thesis.
**Repeatable:** Repeatable for up to 6 total credit hours.
**Requisites:** Restricted to graduate Biomedical Engineering students only.

**BMEN 7840 (1-6) Independent Study**
Provides opportunities for independent study at the graduate (PhD) level. Subject and/or project agreed upon by the student and instructor to fit the needs of the student.
**Repeatable:** Repeatable for up to 10 total credit hours. Allows multiple enrollment in term.
**Requisites:** Restricted to Biomedical Engineering BMEN-PhD students only.

**BMEN 8990 (1-10) Doctoral Dissertation**
Work with a faculty advisor on a doctoral dissertation.
**Repeatable:** Repeatable for up to 60 total credit hours.
**Requisites:** Restricted to Biomedical Engineering (BMEN) Ph.D. graduate students only.