The course requirements for the BME portion of the additional major are as follows:

The Quality Point Average (QPA) for courses that count toward the additional major must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the additional major.

The additional major in Biomedical Engineering should be declared at the same time when declaring a traditional engineering major.

Biomedical Engineering Overview

Biomedical engineering education at Carnegie Mellon University reflects the belief that a top biomedical engineer must be deeply trained in both a traditional engineering practice and biomedical sciences. The unique additional major program leverages extensive collaborations with sister departments in the College of Engineering and with major medical institutions in Pittsburgh. This collaborative approach, combined with a rigorous engineering education, confers unique depth and breadth to the education of Biomedical Engineering graduates.

Students who elect Biomedical Engineering as a major must also declare a major in one of the traditional engineering disciplines: Chemical Engineering, Civil Engineering, Electrical & Computer Engineering, Environmental Engineering, Materials Science & Engineering, or Mechanical Engineering.

The curriculum, demanding but readily feasible to complete in four years, is highly rewarding to motivated students.

Common Requirements for the Additional Major

The Biomedical Engineering additional major program takes advantage of curricular overlaps between Biomedical Engineering and traditional engineering majors, such that the additional major can be completed in four years with only a modest increase in course requirements. The requirements for Biomedical Engineering consist of the core, the tracks, and the capstone design course. The core exposes students to basic facets of biomedical engineering to lay a foundation. The tracks allow students to build depth in a specific aspect of biomedical engineering. The capstone design (https://www.cmu.edu/bme/Academics/undergraduate-programs/Resources/undergrad_design.html) project engages students in teamwork to develop real-world applications.

The additional major in Biomedical Engineering should be declared at the same time when declaring a traditional engineering major.

Course Requirements for the Additional Major

Minimum units required for additional major: 93–102

Students majoring in Biomedical Engineering must meet three sets of requirements:

1. Biomedical Engineering (BME)
2. A traditional engineering discipline, and

The Quality Point Average (QPA) for courses that count toward the additional major must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the additional major.

The course requirements for the BME portion of the additional major are as follows:

Core Courses

(all required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>03-121</td>
<td>Modern Biology- Fall and Spring</td>
<td>9</td>
</tr>
<tr>
<td>03-151</td>
<td>Modern Biology</td>
<td></td>
</tr>
<tr>
<td>42-101</td>
<td>Introduction to Biomedical Engineering- Fall and Spring</td>
<td>12</td>
</tr>
<tr>
<td>42-201</td>
<td>Professional Issues in Biomedical Engineering- Fall and Spring</td>
<td>3</td>
</tr>
<tr>
<td>42-202</td>
<td>Physiology- Fall and Spring</td>
<td>9</td>
</tr>
<tr>
<td>42-203</td>
<td>Biomedical Engineering Laboratory- Fall and Spring</td>
<td>9</td>
</tr>
<tr>
<td>42-302</td>
<td>Biomedical Engineering Systems Modeling and Analysis- Fall and Spring</td>
<td>9</td>
</tr>
<tr>
<td>42-401</td>
<td>Foundation of BME Design- Fall*</td>
<td>6</td>
</tr>
<tr>
<td>42-402</td>
<td>BME Design Project- Spring</td>
<td>9</td>
</tr>
</tbody>
</table>

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# Also known as 03-206 for Health Professions Program (http://www.cmu.edu/hpp/) students.

42-401 serves as the precursor/pre-requisite for 42-402 BME Design Project.

Tracks (Completion of one track is required)

- Biomaterials and Tissue Engineering (BMTE (p. 1))
- Biomechanics (BMEC (p. 2))
- Biomedical Devices (BMDV (p. 2))
- Biomedical Signal and Image Processing (BSIP (p. 3))
- Cellular and Molecular Biotechnology (CMBT (p. 3))
- Neuroengineering (Neuro (p. 3))
- Self-Designed Biomedical Engineering (SBME (p. 4))

Biomaterials and Tissue Engineering (BMTE) Track

Overview

The BMTE track addresses issues at the interface of materials science, biology and engineering. The topics include the interactions between materials and cells or tissues, the effects of such interactions on cells and tissues, the design of materials for biological applications, and the engineering of new tissues.

Targets

The BMTE track is ideal for students interested in combining the education of Biomedical Engineering with Materials Science & Engineering or with Chemical Engineering. Both provide the necessary foundation in chemistry and/or materials science. Students of this track may develop careers in biotechnology, tissue engineering, biopharmaceuticals, and medical devices that leverage materials properties.

Requirements

In addition to the Biomedical Engineering core courses, students in the BMTE Track must take the following combination of three courses:

- One (1) Required BMTE elective
- Two (2) BMTE Electives (either Required or Additional)

BMTE Electives

Required BMTE Electives (must take one of the following)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>42-611</td>
<td>Biomaterials</td>
<td>12</td>
</tr>
<tr>
<td>42-612/27-520</td>
<td>Tissue Engineering</td>
<td>12</td>
</tr>
<tr>
<td>42-615</td>
<td>Biomaterial Host Interactions in Regenerative Medicine</td>
<td>12</td>
</tr>
<tr>
<td>42-667</td>
<td>Biofabrication and Bioprinting</td>
<td>12</td>
</tr>
</tbody>
</table>
Additional BMTE Electives

- 42-613 Polymeric Biomaterials 12
- 42-616 Bio-nanotechnology: Principles and Applications 9
- 42-620 Engineering Molecular Cell Biology 12
- 42-624 Biological Transport and Drug Delivery 9
- 03-320 Cell Biology 9
- 42-x00 BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine) 9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Additional BMDV Electives

- 42-444 Medical Devices 9
- 42-611 Biomaterials 12
- 42-616 Bio-nanotechnology: Principles and Applications 9
- 42-630 Introduction to Neural Engineering 12
- 42-641 Rehabilitation Engineering 9
- 42-648 Cardiovascular Mechanics 12
- 42-650 Introduction to Biomedical Imaging 9
- 42-652/18-416 Nano-Bio-Photonics 12
- 42-675 Fundamentals of Computational Biomedical Engineering 12
- 16-467 Medical Robotics 12
- 18-412 Neural Technology: Sensing and Stimulation 12
- 42-6XX Clinical Course (Surgery for Engineers/ Precision Medicine/ICU Medicine) 9
- 42-x00 BME Research* or 39-500 CIT Honors Thesis 9

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.

Biomedical Devices (BMDV) Track

Overview

The BMDV track addresses issues at the interface of medicine and engineering. The topics include biomedical sensors, actuators, diagnostic devices, therapeutic devices, instruments, systems, and fundamental topics of device material, device fabrication, and device interaction with biological cells, tissues and organs. The Biomedical Device Track will prepare students for roles in the biomedical device industry and further education in graduate/medical schools.

Targets

The BMDV track will prepare students to be leaders in the biomedical device industry and for further education in graduate/medical schools. It is ideal for students interested in combining the education of Biomedical Engineering with Electrical and Computer Engineering, or with Mechanical Engineering, or with Materials Science & Engineering.

Requirements

In addition to the Biomedical Engineering core courses, students in the BMDV Track must take the following combination of three courses:

- One (1) Required BMDV Elective
- Two (2) BMDV Electives (either Required or Additional)

BMDV Electives

Required BMDV Electives (must take at least one of the following)

- 42-660 Bioinstrumentation 12
- 42-678 Medical Device Innovation and Realization 12
- 42-693 Special Topics in Integrated Systems Technology: Micro/Nano Biomedical Devices 12
- 42-694 Engineering Principles of Medical Devices 9

Additional BMDV Electives

- 42-641 Rehabilitation Engineering 9
- 42-648 Cardiovascular Mechanics 12
- 16-467 Medical Robotics 12
- 18-412 Neural Technology: Sensing and Stimulation 12
- 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine) 9
- 42-x00 BME Research* or 39-500 CIT Honors Thesis 9

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.
Biomedical Signal and Image Processing (BSIP) Track

OVERVIEW
The BSIP track addresses biomedical phenomena based on the information embedded in sensor-detected signals, including digital images and nerve electrical pulses. Students in this track will gain an understanding of the technologies involved in acquiring signals and images, the mathematical principles underlying the processing and analysis of signals, and the applications of signal/image processing methods in basic research and medicine.

TARGETS
This track aligns most naturally with a combined education of Biomedical Engineering and Electrical & Computer Engineering, which lays a solid foundation in signal processing principles. This track prepares students for careers in medical imaging or smart prosthetics. It also interfaces with many clinical practices including radiology, neurology/neurosurgery, and pathology.

REQUIREMENTS
In addition to the Biomedical Engineering core courses, students in the BSIP Track must take the following combination of three courses:

- One (1) Required BSIP elective
- Two (2) BSIP Electives (either Required or Additional)

BSIP ELECTIVES

Required BSIP Electives (must take at least one of the following)

- 42-650 Introduction to Biomedical Imaging 9
- 42-668 "Fun"-damentals of MRI and Neuroimaging Analysis 9
- 42-631 Neural Data Analysis 12
- 42-632 Neural Signal Processing 12

Additional BSIP Electives

- 42-437 Biomedical Optical Imaging 9
- 42-640/24-658 Image-Based Computational Modeling and Analysis 12
- 42-656 Introduction to Machine Learning for Biomedical Engineers 9
- 42-660 Bioinstrumentation 12
- 42-675 Fundamentals of Computational Biomedical Engineering 12
- 16-725 (Bio)Medical Image Analysis 12
- 18-491 Digital Signal Processing 12
- 42-x00 BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine) 9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.

Cellular and Molecular Biotechnology (CMBT) Track

Overview
The CMBT track emphasizes fundamentals and applications of biochemistry, biophysics, and cell biology, and processes on the nanometer to micrometer size scale. Students in this track acquire understanding of the molecular and cellular bases of life processes, and build skills in quantitative modeling of live cell-based biotechnologies and in technologies that exploit the unique properties of biomolecules in non-biological settings.

Targets
The CMBT track is ideally suited for the combined education of Biomedical Engineering and Chemical Engineering, which provides a strong core of chemistry and molecular processing principles. The track may also interest students of Mechanical Engineering, Materials Science & Engineering, or Civil & Environmental Engineering who have an interest in molecular aspects of Biomedical Engineering. The CMBT track prepares students for careers in bio/pharmaceutical, medical diagnostics, biosensors, drug delivery, and biological aspects of environmental engineering.

Requirements
In addition to the Biomedical Engineering core courses, students in the CMBT Track must take the following combination of three courses:

- One (1) Required CMBT Elective
- Two (2) CMBT Electives (either Required or Additional)

CMBT Electives

Required CMBT Electives (must take at least one of the following)

- 42-620 Engineering Molecular Cell Biology 12
- 42-621 Principles of Imunoengineering and Development of Immunotherapy Drugs 9
- 42-624 Biological Transport and Drug Delivery 9

Additional CMBT Electives

- 42-616 Bio-nanotechnology: Principles and Applications 9
- 42-626 Drug Delivery Systems 9
- 42-645/24-655 Cellular Biomechanics 9
- 03-320 Cell Biology 9
- 06-722 Bioprocess Design 12
- 42-x00 BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine) 9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.

Neuroengineering (Neuro) Track

Overview
The Neuroengineering (Neuro) track uses engineering techniques to examine, understand, and apply the properties of complex neural systems. Areas of interest include the research and development of neuroengineering technologies for sensing, interfacing, imaging, and modulating the nervous systems. Examples of applications include brain-computer interfaces for use in paralyzed, neural stimulation device design for sensory and motor prostheses and basic science research, and neural recording and imaging devices.

Targets
This track aligns most naturally with a combined education of Biomedical Engineering and Electrical & Computer Engineering, which lays a solid foundation in signal processing principles. This track prepares students for careers in brain-computer interfaces, neural stimulators, and neuroprosthetics.

Requirements
In addition to the Biomedical Engineering core courses, students in the BMEC Track must take the following combination of three courses:

- One (1) Required Neuro Elective
- Two (2) Neuro Electives (either Required or Additional)
4  Department of Biomedical Engineering

Neuro Electives

Required Neuro Electives (must take at least one of the following)

42-630  Introduction to Neural Engineering  12
42-631  Neural Data Analysis  12
42-632  Neural Signal Processing  12

Additional Neuro Electives

42-437  Biomedical Optical Imaging  9
42-641  Rehabilitation Engineering  9
42-650  Introduction to Biomedical Imaging  9
42-652/418-416  Nano-Bio-Photonics  12
42-656  Introduction to Machine Learning for Biomedical Engineers  9
42-660  Bioinstrumentation  12
42-783  Neural Engineering Laboratory  12
15-386  Neural Computation  9
18-370  Fundamentals of Control  12
18-412  Neural Technology: Sensing and Stimulation  12
18-460  Optimization  12

* The 42-400 research project (42-200/300/400 with Honors Research) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the Biomedical Engineering Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.

Self-Designed Biomedical Engineering (SBME) Track

The SBME track is designed for students with a strong sense of career direction that falls beyond the scope of regular Biomedical Engineering tracks. Students are allowed to design the "track" portion of the curriculum in consultation with the faculty. Example themes include medical robotics, embedded medical systems, or computational biomedical engineering.

Requirements

In addition to the Biomedical Engineering core requirements, students must take three elective courses of at least 9 units each. These elective courses must form a coherent theme that is relevant to biomedical engineering. In addition, at least one of the elective courses must be judged by the Biomedical Engineering Undergraduate Affairs Committee to have substantial biological or medical content.

If undergraduate research is part of the SBME track, the research project must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Petition Procedure

1. Students wishing to pursue a self-designed track should first consult with Kristin Kropf (https://engineering.cmu.edu/directory/bios/kropf-kristin.html) (Undergraduate Program and Alumni Relations Coordinator). 2. A SBME track proposal must be submitted electronically to Kristin Kropf (https://engineering.cmu.edu/directory/bios/kropf-kristin.html) at least three weeks prior to Pre-Registration during the spring of the sophomore year. The proposal must include:
   - The three courses of the designed track, including catalog descriptions and when these courses are expected to be taken.
   - A justification of how these courses form a coherent theme relevant to biomedical engineering and why the regular tracks do not relate to the proposed theme
   - Two alternative courses that may substitute for one of the proposed courses, in case the original course is not available.

3. Once approved by the Biomedical Engineering Undergraduate Affairs Committee, the student must sign an agreement listing the theme and the three courses comprising the SBME track.

4. In the event that issues beyond the student's control, such as course scheduling or cancellation, prevent the student from completing the approved course plan, the student may petition the Biomedical Engineering Undergraduate Affairs Committee to
   - Substitute a course with another course that fits the approved theme, OR
   - Complete one of the regular tracks (all classes)

Minor in Biomedical Engineering

Kristin Kropf, Undergraduate Program and Alumni Relations Coordinator, Biomedical Engineering
Email: kgaluska@andrew.cmu.edu

The minor program is designed for students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is open to students of all colleges and is popular among both engineering and science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

The Biomedical Engineering minor curriculum is comprised of three core courses and three electives. The Quality Point Average (QPA) for courses that count toward the minor must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted toward the minor.

Students who have questions or are interested in declaring Biomedical Engineering minor should contact Kristin Kropf (kgaluska@andrew.cmu.edu).

Requirements

Minimum units required for minor: 57

03-121  Modern Biology  9
or 03-151  Honors Modern Biology
42-101  Introduction to Biomedical Engineering  12
42-202  Physiology  9
42-xxx  BME Elective I  9-12
42-xxx  BME Elective II  9-12
42-xxx  BME Elective III  9-12

A BME Elective is defined as one of the following:

1. One semester of 42-200 Sophomore BME Research Project, 42-300 Junior BME Research Project, 42-400 Senior BME Research Project or 39-500 Honors Research Project. The project must be supervised by a core or courtesy Biomedical Engineering faculty member for 9 or more units. Research projects supervised by a courtesy Biomedical Engineering faculty member must have significant biomedical engineering relevance. Note that BME Research Project can only count as one BME elective.

2. 42-203 BME Laboratory (or the cross-listed version 03-206 for students in the Health Professions Program). Please note that priority for enrollment in 42-203 or 03-206 will be given to students who have declared the Additional Major in Biomedical Engineering. If sufficient room in the course remains after all majors have been accommodated in a given semester, students who have declared the Biomedical Engineering Designated Minor will be given the next priority for enrollment. If space still allows, other students will be enrolled.

3. Any 42-xxx course with a course number greater than 42-300 and worth at least 9 units (excluding 42-300 and 42-400- see previous comment regarding BME Research Project).

Note that non-BME, track elective courses for BME major do not automatically qualify as BME minor electives. Students can petition the Biomedical Engineering Undergraduate Affairs Committee to count non-BME classes that have significant biological/medical and engineering contents towards the minor requirements. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Full-Time Faculty

ABIBOTT, ROSALYN, Assistant Professor of Biomedical Engineering – Ph.D., University of Vermont, 2011;

BARATTI FARIMANI, AMIR, Assistant Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., University of Illinois at Urbana-Champaign, 2015;

BARTH, ALISON L., Professor, Biological Sciences, and Biomedical Engineering – Ph.D., University of California, Berkeley, 1997;
ZAPANTA, CONRAD M., Associate Dean of Undergraduate Studies, College of Engineering and Teaching Professor, Biomedical Engineering – Ph.D., The Pennsylvania State University, 1997;

ZHANG, YONGJIE JESSICA, George Tallman Ladd and Florence Barrett Ladd Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., University of Texas at Austin, 2005;

ZHENG, SIYANG, Professor, Biomedical Engineering and Electrical and Computer Engineering – Ph.D., California Institute of Technology, 2007;