UNIVERSITY OF MINNESOTA
Driven to Discover℠

Twin Cities Campus

Biomedical Engineering B.Bm.E.

Department of Biomedical Engineering

College of Science and Engineering

- Program Type: Baccalaureate
- Requirements for this program are current for Spring 2020
- Required credits to graduate with this degree: 124
- Required credits within the major: 108
- Degree: Bachelor of Biomedical Engineering

Biomedical engineers apply the fundamentals of mathematics, physics, chemistry, and biology to solve medically relevant problems. Examples of biomedical engineering activities include medical device design, fabrication and testing, prosthesis fabrication, ergonomics and human factors, physiological function monitoring, home health care technology development, biomedical informatics, functional imaging and tomography, biomaterial development and biocompatibility, artificial tissue and organ fabrication, cell- and biomolecule-based sensors and therapeutics, gene therapy development, and biomedical microsystems.

The program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org.

Program Delivery

This program is available:

- via classroom (the majority of instruction is face-to-face)

Admission Requirements

Students must complete 10 courses before admission to the program.

Freshman and transfer students students are usually admitted to pre-major status before admission to this major

For information about University of Minnesota admission requirements, visit the Office of Admissions website.

Required prerequisites

Mathematics

Calculus I

MATH 1271 - Calculus I [MATH] (4.0 cr)
or MATH 1371 - CSE Calculus I [MATH] (4.0 cr)
or MATH 1571H - Honors Calculus I [MATH] (4.0 cr)

Calculus II

MATH 1272 - Calculus II (4.0 cr)
or MATH 1372 - CSE Calculus II (4.0 cr)
or MATH 1572H - Honors Calculus II (4.0 cr)

Linear Algebra & Differential Equations OR Multivariable Calculus

Both linear algebra and differential equations and multivariable calculus are required to graduate from the program. Only one is required for admission to the program.

Linear Algebra & Differential Equations

MATH 2243 - Linear Algebra and Differential Equations (4.0 cr)
or MATH 2373 - CSE Linear Algebra and Differential Equations (4.0 cr)
or MATH 2574H - Honors Calculus IV (4.0 cr)

or **Multivariable Calculus**

MATH 2263 - Multivariable Calculus (4.0 cr)
or MATH 2374 - CSE Multivariable Calculus and Vector Analysis (4.0 cr)
or MATH 2573H - Honors Calculus III (4.0 cr)

Physical Sciences

CHEM 1061 - Chemical Principles I [PHYS] (3.0 cr)
or CHEM 1071H - Honors Chemistry I [PHYS] (3.0 cr)
CHEM 1065 - Chemical Principles I Laboratory [PHYS] (1.0 cr)
or CHEM 1075H - Honors Chemistry I Laboratory [PHYS] (1.0 cr)
CHEM 1062 - Chemical Principles II [PHYS] (3.0 cr)
or CHEM 1072H - Honors Chemistry II [PHYS] (3.0 cr)
CHEM 1066 - Chemical Principles II Laboratory [PHYS] (1.0 cr)
or CHEM 1076H - Honors Chemistry II Laboratory [PHYS] (1.0 cr)
CHEM 2301 - Organic Chemistry I (3.0 cr)

Information current as of April 25, 2024

PHYS 1301W - Introductory Physics for Science and Engineering I [PHYS, WI] (4.0 cr)
or PHYS 1401V - Honors Physics I [PHYS, WI] (4.0 cr)
PHYS 1302W - Introductory Physics for Science and Engineering II [PHYS, WI] (4.0 cr)
or PHYS 1402V - Honors Physics II [PHYS, WI] (4.0 cr)

Preparatory Courses
BMEN 2401 - Programming for Biomedical Engineers (2.0 cr)
BMEN 2501 - Cellular and Molecular Biology for Biomedical Engineers [BIOL] (4.0 cr)

General Requirements
All students are required to complete general University and college requirements including writing and liberal education courses. For more information about University-wide requirements, see the liberal education requirements.Required courses for the major or minor in which a student receives a D grade (with or without plus or minus) do not count toward the major or minor (including transfer courses).

Program Requirements
All freshmen in the College of Science and Engineering must complete CSE 1001: First-Year Experience.

Statistics
STAT 3021 - Introduction to Probability and Statistics (3.0 cr)

Major Courses
BMEN 1601 - Biomedical Engineering Undergraduate Seminar I (1.0 cr)
BMEN 1602 - Biomedical Engineering Undergraduate Seminar II (1.0 cr)
BMEN 3011 - Biomechanics (3.0 cr)
BMEN 3111 - Biomedical Transport Processes (3.0 cr)
BMEN 3211 - Bioelectricity and Bioinstrumentation (3.0 cr)
BMEN 3311 - Biomaterials (3.0 cr)
BMEN 3411 - Biomedical Systems Analysis (3.0 cr)
BMEN 4001W - Biomedical Engineering Design I [WI] (3.0 cr)
BMEN 4002W - Biomedical Engineering Design II [WI] (3.0 cr)
PHSL 3061 - Principles of Physiology (4.0 cr)
PHSL 3701 - Physiology Laboratory (2.0 cr)
BMEN 2101 - Biomedical Thermodynamics and Kinetics (3.0 cr)
BMEN 3015 - Biomechanics Lab (1.0 cr)
BMEN 3215 - Bioelectricity and Bioinstrumentation Lab (1.0 cr)
BMEN 3315 - Biomaterials Lab (1.0 cr)
BMEN 3115 - Biomedical Transport Processes Lab (1.0 cr)
BMEN 3415 - Biomedical Systems Analysis Lab (1.0 cr)

Linear Algebra & Differential Equations OR Multivariable Calculus
Students must completely both linear algebra & differential equations and multivariable calculus to graduate from this program. One of these courses must be taken prior to enrollment in the program.
Linear Algebra & Differential Equations
MATH 2243 - Linear Algebra and Differential Equations (4.0 cr)
or MATH 2373 - CSE Linear Algebra and Differential Equations (4.0 cr)
or MATH 2574H - Honors Calculus IV (4.0 cr)
or **Multivariable Calculus**
MATH 2263 - Multivariable Calculus (4.0 cr)
or MATH 2374 - CSE Multivariable Calculus and Vector Analysis (4.0 cr)
or MATH 2573H - Honors Calculus III (4.0 cr)

Upper Division Writing Intensive within the Major
Students are required to take one upper division writing intensive course within the major. If that requirement has not been satisfied within the core major requirements, students must choose one course from the following list. Some of these courses may also fulfill other major requirements.
Take 0 - 1 course(s) from the following:
•BMEN 4001W - Biomedical Engineering Design I [WI] (3.0 cr)
•BMEN 4002W - Biomedical Engineering Design II [WI] (3.0 cr)

Program Sub-plans

Students are required to complete one of the following sub-plans.

Bioelectricity/Bioinstrumentation

In bioelectricity/instrumentation (BEI), we seek to record, process, image, and control biomedical signals and develop instrumentation for biological research and medical applications. Specific examples of bioelectricity and instrumentation include cardiac pacemakers for restoring heart rhythm, braincomputer interfaces to link the brain and environment, and anatomical and functional imaging systems (optical, ultrasound or magnetic resonance imaging) to assess tissue conditions at various scales and resolution. Past students in the BEI emphasis area have gone on to work in industry immediately following graduation or to study in graduate school or medical school.

It is necessary that the engineering and science elective (ESE) courses be technically coherent and that the courses be mainly in engineering and at an advanced level. In terms of specific requirements: 1. A specific sub-plan (which includes the option of developing a custom sub-plan) must be declared. 2. A maximum of 13 credits of pure science may be counted toward the total. The remaining 14 or more credits must be in engineering or in technical courses (i.e. courses offered through science and medical departments/programs) having significant engineering content, as determined by the appropriate Sub-Plan Advisor (SPA) in consultation with the Director of Undergraduate Studies (DUS) using the definition of engineering credits. The definition of engineering credits is: a. Any course offered by an engineering program, or b. Any course (or course component) that teaches students how to practically apply the knowledge of pure sciences. Students must consult the DUS about the number of engineering credits allowed for such courses. 3. A maximum of 4 credits of 1000 and 2000 level courses may be counted toward the total. 4. A minimum of 19 credits at the 4000 level or higher. 5. A maximum of 6 credits of Directed Research, Directed Study, and/or Industrial Assignment (co-op) may be counted toward the total, and no more than 4 credits of Directed Study may be counted toward the total. Below is a list of suggested courses for your sub-plan. Upon entry to BME upper-division, students will be required to attend an information session and will be provided with additional resources/instructions which will further assist with selecting a course plan from the below list.

Students should review the course descriptions and select an appropriate set of courses consistent with the degree requirements. Students should then enter the selected courses on the Engineering and Science Elective (ESE) Planning Worksheet and schedule a meeting with the appropriate Sub-Plan Advisor (SPA). Students should discuss their ESE course plans and obtain the signature/approval of the appropriate SPA on the ESE worksheet before submitting it to the Director of Undergraduate Studies (DUS) for departmental signature/approval. Department signature/approval of the ESE plan is required for graduation. Changes to the plan must be re-signed/re-approved by the SPA and DUS. It is important to note that the list below is not definitive. Should you find a course that is not listed below that you feel would be beneficial to your ESE course plan, you can present it to SPA and get their approval to count said course towards your ESE requirements. All students must meet with their SPA to get approval on their first ESE worksheet. Thereafter, changes to your ESE course plan can be approved via SPA signature (meeting not required but is encouraged).

Bioelec/Bioinstr

Take 7 or more course(s) totaling 27 or more credit(s) from the following:

Engineering

Take 14 or more credit(s) from the following:

- EE 4231 - Linear Control Systems: Designed by Input/Output Methods (3.0 cr)
- EE 4235 - Linear Control Systems Laboratory (1.0 cr)
- EE 4233 - State Space Control System Design (3.0 cr)
- EE 4237 - State Space Control Laboratory (1.0 cr)
- EE 4501 - Communications Systems (3.0 cr)
- EE 4505 - Communications Systems Laboratory (1.0 cr)
- BMEN 4011 - CAD/CAE of Bioelectrical Devices (1.0 cr)
- BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
- EE 4111 - Advanced Analog Electronics Design (4.0 cr)
- EE 4541 - Digital Signal Processing (3.0 cr)
- EE 4701 - Electric Drives (3.0 cr)
- EE 5545 - Digital Signal Processing Design (3.0 cr)
- EE 5621 - Physical Optics (3.0 cr)
- EE 5622 - Physical Optics Laboratory (1.0 cr)
- BMEN 5111 - Biomedical Ultrasound (3.0 cr)
- BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
- BMEN 5411 - Neural Engineering (3.0 cr)
- BMEN 5421 - Introduction to Biomedical Optics (3.0 cr)
- EE 3115 - Analog Electronics (3.0 cr)
- EE 3161 - Semiconductor Devices (3.0 cr)
- EE 3601 - Transmission Lines, Fields, and Waves (3.0 cr)
- BMEN 4013 - CAD of Biomechanical/transport Devices (1.0 cr)
- BMEN 4015 - CAE of Biomechanical/Transport Devices (1.0 cr)
- BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
- EE 3101 - Signals, Circuits and Electronics Laboratory (1.0 cr)
- BMEN 3601 - Biomedical Engineering Careers and Practice in the Med Tech Industry (1.0 cr)
- BMEN 4996W - Industrial Assignment II: Co-op Program [WI] (4.0 cr)
- BMEN 4896 - Industrial Assignment I: Co-op Program (2.0 cr)
- BMEN 4793 - Directed Study (1.0 - 4.0 cr)

•BMEN 4794H - Directed Research Honors (1.0 - 4.0 cr)
•IE 5522 - Quality Engineering and Reliability (4.0 cr)
•EE 4607 - Wireless Hardware System Design (3.0 cr)

•Science

Take 0 or more credit(s) from the following:
•BIOC 5444 - Muscle (3.0 cr)
•PHSL 5444 - Muscle (3.0 cr)
•PHSL 5510 - Advanced Cardiac Physiology and Anatomy (2.0 - 3.0 cr)
•PHYS 2601 - Quantum Physics (4.0 cr)
•PHYS 4002 - Electricity and Magnetism (4.0 cr)
•STAT 5303 - Designing Experiments (4.0 cr)
•PHYS 5401 *{Inactive}*(4.0 cr)
•RSC 5841 - Applied Data Acquisition and Processing (3.0 cr)

Biomaterials

Students in the emphasis area of biomaterials are expected to become acquainted with the general principles of designing, synthesizing, processing, and characterizing biomaterials and learn to use biomaterials to solve problems in biology and medicine. Courses on life science, fundamentals of materials science and engineering, and interactions between materials and living elements are relevant.

It is necessary that the engineering and science elective (ESE) courses be technically coherent and that the courses be mainly in engineering and at an advanced level. In terms of specific requirements: 1. A specific sub-plan (which includes the option of developing a custom sub-plan) must be declared. 2. A maximum of 13 credits of pure science may be counted toward the total. The remaining 14 or more credits must be in engineering or in technical courses (i.e. courses offered through science and medical departments/programs) having significant engineering content, as determined by the appropriate Sub-Plan Advisor (SPA) in consultation with the Director of Undergraduate Studies (DUS) using the definition of engineering credits. The definition of engineering credits is: a. Any course offered by an engineering program, or b. Any course (or course component) that teaches students how to practically apply the knowledge of pure sciences. Students must consult the DUS about the number of engineering credits allowed for such courses. 3. A maximum of 4 credits of 1000 and 2000 level courses may be counted toward the total. 4. A minimum of 19 credits at the 4000 level or higher. 5. A maximum of 6 credits of Directed Research, Directed Study, and/or Industrial Assignment (co-op) may be counted toward the total, and no more than 4 credits of Directed Study may be counted toward the total. Below is a list of suggested courses for your sub-plan. Upon entry to BME upper-division, students will be required to attend an information session and will be provided with additional resources/instructions which will further assist with selecting a course plan from the below list.

Students should review the course descriptions and select an appropriate set of courses consistent with the degree requirements. Students should then enter the selected courses on the Engineering and Science Elective (ESE) Planning Worksheet and schedule a meeting with the appropriate Sub-Plan Advisor (SPA). Students should discuss their ESE course plans and obtain the signature/approval of the appropriate SPA on the ESE worksheet before submitting it to the Director of Undergraduate Studies (DUS) for departmental signature/approval. Department signature/approval of the ESE plan is required for graduation. Changes to the plan must be re-signed/re-approved by the SPA and DUS. It is important to note that the list below is not definitive. Should you find a course that is not listed below that you feel would be beneficial to your ESE course plan, you can present it to SPA and get their approval to count said course towards your ESE requirements. All students must meet with their SPA to get approval on their first ESE worksheet. Thereafter, changes to your ESE course plan can be approved via SPA signature (meeting not required but is encouraged).

Biomaterials

Take 7 or more course(s) totaling 27 or more credit(s) from the following:

Engineering

Take 14 or more credit(s) from the following:
•BMEN 5001 - Advanced Biomaterials (3.0 cr)
•CHEN 4214 - Polymers (3.0 cr)
•MATS 4214 - Polymers (3.0 cr)
•MATS 4221 - Materials Performance (4.0 cr)
•MATS 4301W - Materials Processing [WI] (4.0 cr)
•MATS 3001 - Thermodynamics of Materials (3.0 cr)
•BMEN 5041 - Tissue Engineering (3.0 cr)
•MATS 3801 - Structural Characterization Lab (4.0 cr)
•MATS 3012 - Metals and Alloys (3.0 cr)
•AEM 4511 - Mechanics of Composite Materials (3.0 cr)
•BMEN 5201 - Advanced Biomechanics (3.0 cr)
•AEM 3031 - Deformable Body Mechanics (3.0 cr)
•MATS 4212 - Ceramics (3.0 cr)
•BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
•BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
•BMEN 5351 - Cell Engineering (3.0 cr)
•BMEN 5701 - Cancer Bioengineering (3.0 cr)
•BMEN 4896 - Industrial Assignment I: Co-op Program (2.0 cr)

•BMEN 4996W - Industrial Assignment II: Co-op Program [WI] (4.0 cr)
•BMEN 4793 - Directed Study (1.0 - 4.0 cr)
•BMEN 4794H - Directed Research Honors (1.0 - 4.0 cr)
•BMEN 4794 - Directed Research (1.0 - 4.0 cr)
•AEM 4581 - Mechanics of Solids (3.0 cr)

•Science

Take 0 or more credit(s) from the following:
•MICB 4131 - Immunology (3.0 cr)
•PHYS 4911 - Introduction to Biopolymer Physics (3.0 cr)
•CHEM 2302 - Organic Chemistry II (3.0 cr)
•CHEM 2311 - Organic Lab (4.0 cr)
•BIOC 3021 - Biochemistry (3.0 cr)
•BIOL 4004 - Cell Biology (3.0 cr)
•BIOC 5444 - Muscle (3.0 cr)
•PHSL 5444 - Muscle (3.0 cr)
•GCD 4111 - Histology: Cell and Tissue Organization (4.0 cr)

Biomechanics

The area of biomechanics is extremely broad, so before planning your electives, you should decide which of the two basic sub disciplines is of greater interest to you: 1) Mechanics of Tissues and Biomaterials this area emphasizes understanding how biological and biomedical materials deform under load. You will be preparing yourself to work on tissue mechanics problems (e.g., how much does a vessel expand in response to a change in pressure, how much does a heart valve leaflet deflect under a given load, or how much does a tendon stretch given a certain amount of tension) as well as on mechanical aspects of biomaterials selection (e.g., what vascular graft or stent materials would provide a good match to the native tissue?). 2) Kinematics and Biomechanical Design this area emphasizes the design of biomechanical devices and how linkage systems behave. You will be preparing yourself to work on the design of mechanical systems for biomedical use (e.g., how one should design a knee brace to be as light as possible but still provide the necessary support) and to understand the dynamics of large scale motions (e.g., what causes the characteristic features of the various gait irregularities and how can they be corrected?).

It is necessary that the engineering and science elective (ESE) courses be technically coherent and that the courses be mainly in engineering and at an advanced level. In terms of specific requirements: 1. A specific sub-plan (which includes the option of developing a custom sub-plan) must be declared. 2. A maximum of 13 credits of pure science may be counted toward the total. The remaining 14 or more credits must be in engineering or in technical courses (i.e. courses offered through science and medical departments/programs) having significant engineering content, as determined by the appropriate Sub-Plan Advisor (SPA) in consultation with the Director of Undergraduate Studies (DUS) using the definition of engineering credits. The definition of engineering credits is: a. Any course offered by an engineering program, or b. Any course (or course component) that teaches students how to practically apply the knowledge of pure sciences. Students must consult the DUS about the number of engineering credits allowed for such courses. 3. A maximum of 4 credits of 1000 and 2000 level courses may be counted toward the total. 4. A minimum of 19 credits at the 4000 level or higher. 5. A maximum of 6 credits of Directed Research, Directed Study, and/or Industrial Assignment (co-op) may be counted toward the total, and no more than 4 credits of Directed Study may be counted toward the total. Below is a list of suggested courses for your sub-plan. Upon entry to BME upper-division, students will be required to attend an information session and will be provided with additional resources/instructions which will further assist with selecting a course plan from the below list.

Students should review the course descriptions and select an appropriate set of courses consistent with the degree requirements. Students should then enter the selected courses on the Engineering and Science Elective (ESE) Planning Worksheet and schedule a meeting with the appropriate Sub-Plan Advisor (SPA). Students should discuss their ESE course plans and obtain the signature/approval of the appropriate SPA on the ESE worksheet before submitting it to the Director of Undergraduate Studies (DUS) for departmental signature/approval. Department signature/approval of the ESE plan is required for graduation. Changes to the plan must be re-signed/re-approved by the SPA and DUS. It is important to note that the list below is not definitive. Should you find a course that is not listed below that you feel would be beneficial to your ESE course plan, you can present it to SPA and get their approval to count said course towards your ESE requirements. All students must meet with their SPA to get approval on their first ESE worksheet. Thereafter, changes to your ESE course plan can be approved via SPA signature (meeting not required but is encouraged).

Biomechanics

Take 7 or more course(s) totaling 27 or more credit(s) from the following:

Engineering

Take 14 or more credit(s) from the following:
•AEM 3031 - Deformable Body Mechanics (3.0 cr)
•BMEN 5201 - Advanced Biomechanics (3.0 cr)
•ME 5228 - Introduction to Finite Element Modeling, Analysis, and Design (4.0 cr)
•AEM 4502 - Computational Structural Analysis (3.0 cr)
•AEM 5501 - Continuum Mechanics (3.0 cr)
•AEM 5503 - Theory of Elasticity (3.0 cr)
•ME 5241 - Computer-Aided Engineering (4.0 cr)
•AEM 4511 - Mechanics of Composite Materials (3.0 cr)
•AEM 4501 - Aerospace Structures (3.0 cr)

- BMEN 5001 - Advanced Biomaterials (3.0 cr)
- BMEN 5041 - Tissue Engineering (3.0 cr)
- BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
- BMEN 4013 - CAD of Biomechanical/transport Devices (1.0 cr)
- BMEN 4015 - CAE of Biomechanical/Transport Devices (1.0 cr)
- MATS 3001 - Thermodynamics of Materials (3.0 cr)
- BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
- BMEN 3601 - Biomedical Engineering Careers and Practice in the Med Tech Industry (1.0 cr)
- BMEN 4896 - Industrial Assignment I: Co-op Program (2.0 cr)
- BMEN 4996W - Industrial Assignment II: Co-op Program [WI] (4.0 cr)
- BMEN 4793 - Directed Study (1.0 - 4.0 cr)
- BMEN 4794H - Directed Research Honors (1.0 - 4.0 cr)
- BMEN 4794 - Directed Research (1.0 - 4.0 cr)
- ME 3221 - Fundamentals of Design & Manufacturing (4.0 cr)
- ME 3222 - Mechanisms & Machine Design (4.0 cr)
- ME 4031W - Basic Mechanical Measurements Laboratory [WI] (4.0 cr)
- ME 4231 - Motion Control Laboratory (4.0 cr)
- IE 5511 - Human Factors and Work Analysis (4.0 cr)
- ME 5281 - Feedback Control Systems (4.0 cr)
- ME 5221 - Computer-Assisted Product Realization (4.0 cr)

- **Science**

Take 0 or more credit(s) from the following:

- RSC 5135 - Advanced Biomechanics I: Kinematics (3.0 cr)
- RSC 5231 - Clinical Biomechanics (2.0 - 5.0 cr)
- BIOC 5444 - Muscle (3.0 cr)
- PHSL 5444 - Muscle (3.0 cr)
- MATH 4242 - Applied Linear Algebra (4.0 cr)
- MATH 5587 - Elementary Partial Differential Equations I (4.0 cr)
- RSC 5235 - Advanced Biomechanics II: Kinetics (3.0 cr)

Biomedical Transport Processes

BTP involves three fundamental processes: momentum transfer, mass transfer, and heat transfer. They share similar biophysical and mathematical descriptions. Momentum transfer underlies flow fluid in the subject known as fluid mechanics. Applications of fluid mechanics in BME range from predicting blood flow in vessels, to flow of samples in "lab on chip" microfluidic systems, to flow of cell culture medium through tissue engineered cartilage in bioreactors. Mass and heat transfer refer to the ability to deliver molecules and energy, respectively, from a source to a target. Applications of mass and heat transfer range from predicting blood oxygenation rates in capillaries from oxygen in lung alveoli and in hollow fibers from pure oxygen gas in "heart lung machines," to movement of mRNA generated in the cell nucleus to cytoplasmic ribosomes. While appropriate and accurate experimentation is also key on this subject, BTP is highly mathematical and computational in nature, since the basis of making such predictions is formulating and solving the equations that govern momentum, mass, and energy balances. This is reflected in the number of mathematical and computational ESE courses listed for this EA. As suggested in the above applications, BTP is relevant in almost every physiological / cellular process and almost all medical devices. Thus, this EA is relevant for students interested in pursuing both employment and advanced studies (MD and PhD) upon graduation.

It is necessary that the engineering and science elective (ESE) courses be technically coherent and that the courses be mainly in engineering and at an advanced level. In terms of specific requirements: 1. A specific sub-plan (which includes the option of developing a custom sub-plan) must be declared. 2. A maximum of 13 credits of pure science may be counted toward the total. The remaining 14 or more credits must be in engineering or in technical courses (i.e. courses offered through science and medical departments/programs) having significant engineering content, as determined by the appropriate Sub-Plan Advisor (SPA) in consultation with the Director of Undergraduate Studies (DUS) using the definition of engineering credits. The definition of engineering credits is: a. Any course offered by an engineering program, or b. Any course (or course component) that teaches students how to practically apply the knowledge of pure sciences. Students must consult the DUS about the number of engineering credits allowed for such courses. 3. A maximum of 4 credits of 1000 and 2000 level courses may be counted toward the total. 4. A minimum of 19 credits at the 4000 level or higher. 5. A maximum of 6 credits of Directed Research, Directed Study, and/or Industrial Assignment (co-op) may be counted toward the total, and no more than 4 credits of Directed Study may be counted toward the total. Below is a list of suggested courses for your sub-plan. Upon entry to BME upper-division, students will be required to attend an information session and will be provided with additional resources/instructions which will further assist with selecting a course plan from the below list.

Students should review the course descriptions and select an appropriate set of courses consistent with the degree requirements. Students should then enter the selected courses on the Engineering and Science Elective (ESE) Planning Worksheet and schedule a meeting with the appropriate Sub-Plan Advisor (SPA). Students should discuss their ESE course plans and obtain the signature/approval of the appropriate SPA on the ESE worksheet before submitting it to the Director of Undergraduate Studies (DUS) for departmental signature/approval. Department signature/approval of the ESE plan is required for graduation. Changes to the plan must be re-signed/re-approved by the SPA and DUS. It is important to note that the list below is not definitive. Should you find a course that is not listed below that you feel would be beneficial to your ESE course plan, you can present it to SPA and get their approval to count said course towards your ESE requirements. All students must meet with their SPA to get approval on their first ESE worksheet.

Thereafter, changes to your ESE course plan can be approved via SPA signature (meeting not required but is encouraged).

Biomedical Transport Processes

Take 7 or more course(s) totaling 27 or more credit(s) from the following:

Engineering

Take 14 or more credit(s) from the following:

- BMEN 4896 - Industrial Assignment I: Co-op Program (2.0 cr)
- BMEN 4996W - Industrial Assignment II: Co-op Program [WI] (4.0 cr)
- BMEN 4793 - Directed Study (1.0 - 4.0 cr)
- BMEN 4794 - Directed Research (1.0 - 4.0 cr)
- BMEN 4794H - Directed Research Honors (1.0 - 4.0 cr)
- BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
- AEM 5253 - Computational Fluid Mechanics (3.0 cr)
- BMEN 5041 - Tissue Engineering (3.0 cr)
- BMEN 5321 - Microfluidics in Biology and Medicine (3.0 cr)
- BMEN 5351 - Cell Engineering (3.0 cr)
- CHEN 4702 - Introduction to Rheology (2.0 cr)
- CHEN 4704 - Advanced Undergraduate Physical Rate Processes I: Transport (3.0 cr)
- ME 5344 - Thermodynamics of Fluid Flow With Applications (4.0 cr)
- AEM 3031 - Deformable Body Mechanics (3.0 cr)
- BBE 4013 - Transport in Biological Processes II (3.0 cr)
- BBE 4713 - Biological Process Engineering (3.0 cr)
- BMEN 5701 - Cancer Bioengineering (3.0 cr)
- CHEN 4701 - Applied Math (3.0 cr)
- CHEN 5751 - Biochemical Engineering (3.0 cr)
- ME 5228 - Introduction to Finite Element Modeling, Analysis, and Design (4.0 cr)
- CEGE 5543 - Introductory Environmental Fluid Mechanics (4.0 cr)
- CHEN 5531 *{Inactive}*(3.0 cr)
- ME 3333 - Heat Transfer (3.0 cr)
- ME 5341 - Case Studies in Thermal Engineering and Design (4.0 cr)
- BMEN 4013 - CAD of Biomechanical/transport Devices (1.0 cr)
- BMEN 4015 - CAE of Biomechanical/Transport Devices (1.0 cr)
- IE 5522 - Quality Engineering and Reliability (4.0 cr)
- BMEN 3601 - Biomedical Engineering Careers and Practice in the Med Tech Industry (1.0 cr)
- CSCI 5304 - Computational Aspects of Matrix Theory (3.0 cr)
- ME 5351 - Computational Heat Transfer (4.0 cr)

Science

Take 0 or more credit(s) from the following:

- MATH 4512 - Differential Equations with Applications (3.0 cr)
- MATH 4567 - Applied Fourier Analysis (4.0 cr)
- MATH 5587 - Elementary Partial Differential Equations I (4.0 cr)
- MATH 5588 - Elementary Partial Differential Equations II (4.0 cr)
- STAT 5303 - Designing Experiments (4.0 cr)

Cell and Molecular Bioengineering

In cell and molecular bioengineering (CMBE), we take advantage of natural biological processes for the advancement of industrial biotechnologies. For example, by harnessing the power of genetic manipulation, we can control cellular production of small molecules, enzymes (catalysts) and other biomolecules that can be used in the treatment of disease and / or in the development of nanoscale medical devices. Additionally, one desperate need is to improve approaches to discovering new drugs, and students in this emphasis area will be well positioned to pursue graduate work and ultimately a career in the pharmaceutical industry.

It is necessary that the engineering and science elective (ESE) courses be technically coherent and that the courses be mainly in engineering and at an advanced level. In terms of specific requirements: 1. A specific sub-plan (which includes the option of developing a custom sub-plan) must be declared. 2. A maximum of 13 credits of pure science may be counted toward the total. The remaining 14 or more credits must be in engineering or in technical courses (i.e. courses offered through science and medical departments/programs) having significant engineering content, as determined by the appropriate Sub-Plan Advisor (SPA) in consultation with the Director of Undergraduate Studies (DUS) using the definition of engineering credits. The definition of engineering credits is: a. Any course offered by an engineering program, or b. Any course (or course component) that teaches students how to practically apply the knowledge of pure sciences. Students must consult the DUS about the number of engineering credits allowed for such courses. 3. A maximum of 4 credits of 1000 and 2000 level courses may be counted toward the total. 4. A minimum of 19 credits at the 4000 level or higher. 5. A maximum of 6 credits of Directed Research, Directed Study, and/or Industrial Assignment (co-op) may be counted toward the total, and no more than 4 credits of Directed Study may be counted toward the total. Below is a list of suggested courses for your sub-plan. Upon entry to BME upper-division, students will be required to attend an information session and will be provided with additional resources/instructions which will further assist with selecting a course plan from the below list.

Students should review the course descriptions and select an appropriate set of courses consistent with the degree requirements.

Students should then enter the selected courses on the Engineering and Science Elective (ESE) Planning Worksheet and schedule a meeting with the appropriate Sub-Plan Advisor (SPA). Students should discuss their ESE course plans and obtain the signature/approval of the appropriate SPA on the ESE worksheet before submitting it to the Director of Undergraduate Studies (DUS) for departmental signature/approval. Department signature/approval of the ESE plan is required for graduation. Changes to the plan must be re-signed/re-approved by the SPA and DUS. It is important to note that the list below is not definitive. Should you find a course that is not listed below that you feel would be beneficial to your ESE course plan, you can present it to SPA and get their approval to count said course towards your ESE requirements. All students must meet with their SPA to get approval on their first ESE worksheet. Thereafter, changes to your ESE course plan can be approved via SPA signature (meeting not required but is encouraged).

Cell and Molecular Bioengineering

Take 7 or more course(s) totaling 27 or more credit(s) from the following:

Engineering

Take 14 or more credit(s) from the following:

- BMEN 5001 - Advanced Biomaterials (3.0 cr)
- BMEN 5041 - Tissue Engineering (3.0 cr)
- BMEN 5351 - Cell Engineering (3.0 cr)
- CHEN 3102 - Reaction Kinetics and Reactor Engineering (4.0 cr)
- CHEN 5751 - Biochemical Engineering (3.0 cr)
- BMEN 4996W - Industrial Assignment II: Co-op Program [WI] (4.0 cr)
- BMEN 4896 - Industrial Assignment I: Co-op Program (2.0 cr)
- BMEN 4793 - Directed Study (1.0 - 4.0 cr)
- BMEN 4794H - Directed Research Honors (1.0 - 4.0 cr)
- BMEN 4794 - Directed Research (1.0 - 4.0 cr)

Science

Take 0 or more credit(s) from the following:

- BIOC 4125 - Laboratory in Molecular Biology and Biotechnology (3.0 cr)
- BIOC 5351 - Protein Engineering (3.0 cr)
- BIOC 5352 - Biotechnology and Bioengineering for Biochemists (3.0 cr)
- BIOC 4332 - Biochemistry II: Molecular Mechanisms of Signal Transduction and Gene Expression (4.0 cr)
- CHEM 2302 - Organic Chemistry II (3.0 cr)
- MATH 4428 - Mathematical Modeling (4.0 cr)
- MICB 4131 - Immunology (3.0 cr)
- MICB 4235 - Advanced Laboratory: Virology, Immunology, and Microbial Genetics (3.0 cr)
- PHCL 4001 - Mechanisms of Drug Action (2.0 cr)
- CHEM 5245 *{Inactive}*(3.0 cr)
- MEDC 5245 - Introduction to Drug Design (3.0 cr)
- CHEM 2311 - Organic Lab (4.0 cr)

Cell and Tissue Engineering

In cell and tissue engineering (CTE), we seek to control biological function at the cell and tissue level. Specific examples of tissue engineering include bioreactors for controlled physical/chemical stimuli, drug and nutrient transport through tissue, and tissue mechanical properties. Specific examples of cell engineering include control of cell migration, division, growth, and death through therapeutic drugs or other molecular agents, such as those released from drug eluting stents. Students should be aware that there are relatively few bachelors degree level positions that directly relate to CTE. Rather, most of the positions in CTE tend to be filled by PhD level engineers, and so further study is usually required. If a student is considering further study, such as graduate or medical school, this sub-plan will be useful preparation, provided the student is intrinsically interested in CTE.

It is necessary that the engineering and science elective (ESE) courses be technically coherent and that the courses be mainly in engineering and at an advanced level. In terms of specific requirements: 1. A specific sub-plan (which includes the option of developing a custom sub-plan) must be declared. 2. A maximum of 13 credits of pure science may be counted toward the total. The remaining 14 or more credits must be in engineering or in technical courses (i.e. courses offered through science and medical departments/programs) having significant engineering content, as determined by the appropriate Sub-Plan Advisor (SPA) in consultation with the Director of Undergraduate Studies (DUS) using the definition of engineering credits. The definition of engineering credits is: a. Any course offered by an engineering program, or b. Any course (or course component) that teaches students how to practically apply the knowledge of pure sciences. Students must consult the DUS about the number of engineering credits allowed for such courses. 3. A maximum of 4 credits of 1000 and 2000 level courses may be counted toward the total. 4. A minimum of 19 credits at the 4000 level or higher. 5. A maximum of 6 credits of Directed Research, Directed Study, and/or Industrial Assignment (co-op) may be counted toward the total, and no more than 4 credits of Directed Study may be counted toward the total. Below is a list of suggested courses for your sub-plan. Upon entry to BME upper-division, students will be required to attend an information session and will be provided with additional resources/instructions which will further assist with selecting a course plan from the below list.

Students should review the course descriptions and select an appropriate set of courses consistent with the degree requirements. Students should then enter the selected courses on the Engineering and Science Elective (ESE) Planning Worksheet and schedule a meeting with the appropriate Sub-Plan Advisor (SPA). Students should discuss their ESE course plans and obtain the signature/approval of the appropriate SPA on the ESE worksheet before submitting it to the Director of Undergraduate Studies (DUS) for departmental signature/approval. Department signature/approval of the ESE plan is required for graduation. Changes to the plan

must be re-signed/re-approved by the SPA and DUS. It is important to note that the list below is not definitive. Should you find a course that is not listed below that you feel would be beneficial to your ESE course plan, you can present it to SPA and get their approval to count said course towards your ESE requirements. All students must meet with their SPA to get approval on their first ESE worksheet. Thereafter, changes to your ESE course plan can be approved via SPA signature (meeting not required but is encouraged).

Cell and Tissue Engineering

Take 7 or more course(s) totaling 27 or more credit(s) from the following:

Engineering

Take 14 or more credit(s) from the following:

- BMEN 5351 - Cell Engineering (3.0 cr)
- BMEN 5041 - Tissue Engineering (3.0 cr)
- BMEN 4794 - Directed Research (1.0 - 4.0 cr)
- BMEN 4794H - Directed Research Honors (1.0 - 4.0 cr)
- BMEN 4793 - Directed Study (1.0 - 4.0 cr)
- BMEN 4896 - Industrial Assignment I: Co-op Program (2.0 cr)
- BMEN 4996W - Industrial Assignment II: Co-op Program [WI] (4.0 cr)
- AEM 3031 - Deformable Body Mechanics (3.0 cr)
- BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
- BMEN 5001 - Advanced Biomaterials (3.0 cr)
- BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
- BMEN 5201 - Advanced Biomechanics (3.0 cr)
- BMEN 5321 - Microfluidics in Biology and Medicine (3.0 cr)
- BMEN 5601 - Cardiovascular Devices (1.0 cr)
- BMEN 5701 - Cancer Bioengineering (3.0 cr)
- CHEN 5751 - Biochemical Engineering (3.0 cr)
- BMEN 3151 - Medical Device Practicum (1.0 cr)
- ME 5351 - Computational Heat Transfer (4.0 cr)

Science

Take 0 or more credit(s) from the following:

- BIOL 4003 - Genetics (3.0 cr)
- BIOL 4004 - Cell Biology (3.0 cr)
- BIOL 5950 - Special Topics (1.0 - 4.0 cr)
- GCD 4025 - Cell Biology, Development & Regeneration Laboratory (3.0 cr)
- GCD 4034 - Molecular Genetics and Genomics (3.0 cr)
- GCD 4111 - Histology: Cell and Tissue Organization (4.0 cr)
- GCD 4143 - Human Genetics and Genomics (3.0 cr)
- GCD 4151 - Molecular Biology of Cancer (3.0 cr)
- GCD 4161 - Developmental Biology (3.0 cr)
- GCD 4171 - Stem Cells in Biology and Medicine (3.0 cr)
- BIOC 5444 - Muscle (3.0 cr)
- PHSL 5444 - Muscle (3.0 cr)
- MICB 4131 - Immunology (3.0 cr)
- BIOC 5528 - Spectroscopy and Kinetics (4.0 cr)
- KIN 3027 - Human Anatomy for Kinesiology, Physical Activity, and Health Promotion (4.0 cr)
- NEUR 5230 - Cerebrovascular Hemodynamics and Diseases I (4.0 cr)
- NEUR 5240 *{Inactive}*(4.0 cr)
- RSC 5101 - Mathematical Tools for Research Applications in Health, Rehab, and Human Movement Sciences (1.0 cr)
- RSC 5106 - Introduction to Rehabilitation Science (1.0 cr)
- RSC 5135 - Advanced Biomechanics I: Kinematics (3.0 cr)
- RSC 5231 - Clinical Biomechanics (2.0 - 5.0 cr)
- RSC 5281 - Physiology for Physical Rehabilitation (2.0 - 4.0 cr)

Medical Device Design

The medical device area covers an extreme range from implantable coronary artery stents to refrigerator sized blood testers. Some courses, such as Advanced Biomaterials, Computer Aided Product Realization, Quality Engineering, Design and Manufacturing, and Designing Experiments could be helpful for any career in devices. Students interested in electronic devices (which can range from pacemakers to giant blood testers) might consider the EE courses covering Fundamentals, Microsystems, Microcontrollers, Communications, and Analog/Digital Design. Students considering work in the broad area of stimulation and monitoring (pacemakers to nerve stimulators to EKGs) should take Advanced Bioelectricity. For a career in external medical devices (such as cardiac assist, dialysis, or blood testers), the courses on Advanced Biomedical Transport, Electric Drives, Motion Control, Advanced Mechanisms Design, Stress Analysis/Sensing/Transducers, and Robotics are helpful.

It is necessary that the engineering and science elective (ESE) courses be technically coherent and that the courses be mainly in engineering and at an advanced level. In terms of specific requirements: 1. A specific sub-plan (which includes the option of developing a custom sub-plan) must be declared. 2. A maximum of 13 credits of pure science may be counted toward the total. The remaining 14 or more credits must be in engineering or in technical courses (i.e. courses offered through science and medical

departments/programs) having significant engineering content, as determined by the appropriate Sub-Plan Advisor (SPA) in consultation with the Director of Undergraduate Studies (DUS) using the definition of engineering credits. The definition of engineering credits is: a. Any course offered by an engineering program, or b. Any course (or course component) that teaches students how to practically apply the knowledge of pure sciences. Students must consult the DUS about the number of engineering credits allowed for such courses. 3. A maximum of 4 credits of 1000 and 2000 level courses may be counted toward the total. 4. A minimum of 19 credits at the 4000 level or higher. 5. A maximum of 6 credits of Directed Research, Directed Study, and/or Industrial Assignment (co-op) may be counted toward the total, and no more than 4 credits of Directed Study may be counted toward the total. Below is a list of suggested courses for your sub-plan. Upon entry to BME upper-division, students will be required to attend an information session and will be provided with additional resources/instructions which will further assist with selecting a course plan from the below list.

Students should review the course descriptions and select an appropriate set of courses consistent with the degree requirements. Students should then enter the selected courses on the Engineering and Science Elective (ESE) Planning Worksheet and schedule a meeting with the appropriate Sub-Plan Advisor (SPA). Students should discuss their ESE course plans and obtain the signature/approval of the appropriate SPA on the ESE worksheet before submitting it to the Director of Undergraduate Studies (DUS) for departmental signature/approval. Department signature/approval of the ESE plan is required for graduation. Changes to the plan must be re-signed/re-approved by the SPA and DUS. It is important to note that the list below is not definitive. Should you find a course that is not listed below that you feel would be beneficial to your ESE course plan, you can present it to SPA and get their approval to count said course towards your ESE requirements. All students must meet with their SPA to get approval on their first ESE worksheet. Thereafter, changes to your ESE course plan can be approved via SPA signature (meeting not required but is encouraged).

Medical Device Design

Take 7 or more course(s) totaling 27 or more credit(s) from the following:

Engineering

Take 14 or more credit(s) from the following:

- BMEN 3601 - Biomedical Engineering Careers and Practice in the Med Tech Industry (1.0 cr)
- BMEN 5001 - Advanced Biomaterials (3.0 cr)
- BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
- BMEN 5111 - Biomedical Ultrasound (3.0 cr)
- BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
- BMEN 5201 - Advanced Biomechanics (3.0 cr)
- BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
- BMEN 5411 - Neural Engineering (3.0 cr)
- BMEN 5412 - Neuromodulation (3.0 cr)
- BMEN 5413 - Neural Decoding and Interfacing (3.0 cr)
- BMEN 5601 - Cardiovascular Devices (1.0 cr)
- BMEN 4896 - Industrial Assignment I: Co-op Program (2.0 cr)
- BMEN 4996W - Industrial Assignment II: Co-op Program [WI] (4.0 cr)
- BMEN 4793 - Directed Study (1.0 - 4.0 cr)
- BMEN 4794 - Directed Research (1.0 - 4.0 cr)
- BMEN 4794H - Directed Research Honors (1.0 - 4.0 cr)
- BMEN 4011 - CAD/CAE of Bioelectrical Devices (1.0 cr)
- BMEN 4013 - CAD of Biomechanical/transport Devices (1.0 cr)
- BMEN 4015 - CAE of Biomechanical/Transport Devices (1.0 cr)
- ME 5228 - Introduction to Finite Element Modeling, Analysis, and Design (4.0 cr)
- AEM 3031 - Deformable Body Mechanics (3.0 cr)
- CSCI 4511W - Introduction to Artificial Intelligence [WI] (4.0 cr)
- CSCI 5521 - Machine Learning Fundamentals (3.0 cr)
- CSCI 5523 - Introduction to Data Mining (3.0 cr)
- CSCI 5115 - User Interface Design, Implementation and Evaluation (3.0 cr)
- CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
- CSCI 5551 - Introduction to Intelligent Robotic Systems (3.0 cr)
- CSCI 5609 - Visualization (3.0 cr)
- EE 3115 - Analog Electronics (3.0 cr)
- EE 4111 - Advanced Analog Electronics Design (4.0 cr)
- EE 4341 - Embedded System Design (4.0 cr)
- EE 4501 - Communications Systems (3.0 cr)
- EE 4505 - Communications Systems Laboratory (1.0 cr)
- EE 4701 - Electric Drives (3.0 cr)
- EE 4703 - Electric Drives Laboratory (1.0 cr)
- ME 3221 - Fundamentals of Design & Manufacturing (4.0 cr)
- ME 3222 - Mechanisms & Machine Design (4.0 cr)
- ME 4031W - Basic Mechanical Measurements Laboratory [WI] (4.0 cr)
- ME 4231 - Motion Control Laboratory (4.0 cr)
- ME 5223 - Materials in Design (4.0 cr)
- ME 5286 - Robotics (4.0 cr)
- IE 5541 - Project Management (4.0 cr)

- IE 5522 - Quality Engineering and Reliability (4.0 cr)
- BMEN 3151 - Medical Device Practicum (1.0 cr)
- IE 5511 - Human Factors and Work Analysis (4.0 cr)
- EE 2361 - Introduction to Microcontrollers (4.0 cr)

•Science

Take 0 or more credit(s) from the following:

- ANAT 3601 - Principles of Human Anatomy (3.0 cr)
- ANAT 3611 - Principles of Human Anatomy (3.0 cr)
- ANAT 3602 - Principles of Human Anatomy Laboratory (2.0 cr)
- ANAT 3612 - Principles of Human Anatomy Laboratory (2.0 cr)
- ANAT 5150 - Human Gross Anatomy (5.0 cr)
- BIOC 5444 - Muscle (3.0 cr)
- PHSL 5444 - Muscle (3.0 cr)
- CPMS 5101 - Introduction to Clinical Physiology and Movement Science (3.0 cr)
- NSC 5540 - Survey of Biomedical Neuroscience (2.0 cr)
- PHSL 4021 - Advanced Physiology and Bioengineering: Bionic Human (3.0 cr)
- PHSL 5510 - Advanced Cardiac Physiology and Anatomy (2.0 - 3.0 cr)
- PHSL 5525 - Anatomy and Physiology of the Pelvis and Urinary System (1.0 - 2.0 cr)
- KIN 3505 - Intro to Human-Centered Design (3.0 cr)
- KIN 5001 - Foundations of Human Factors/Ergonomics (3.0 cr)
- STAT 5303 - Designing Experiments (4.0 cr)
- RSC 5101 - Mathematical Tools for Research Applications in Health, Rehab, and Human Movement Sciences (1.0 cr)
- RSC 5106 - Introduction to Rehabilitation Science (1.0 cr)
- RSC 5135 - Advanced Biomechanics I: Kinematics (3.0 cr)
- RSC 5231 - Clinical Biomechanics (2.0 - 5.0 cr)
- RSC 5281 - Physiology for Physical Rehabilitation (2.0 - 4.0 cr)
- RSC 5200 - Introduction to Neuromodulation (1.0 - 3.0 cr)
- MATH 5445 - Mathematical Analysis of Biological Networks (4.0 cr)
- STAT 5021 - Statistical Analysis (4.0 cr)

Neural Engineering

In neural engineering, we use engineering principles to understand how the brain works and develop new technology to interact and treat the brain. The curriculum for this emphasis area is designed to teach you the basics of neuroanatomy and neurophysiology and the fundamentals of diseases such as Alzheimers, Parkinsons, tinnitus, and epilepsy. You will also develop engineering skills such as signal processing, image processing, instrumentation and computational modeling as well as electrode design, amplifier and filter design, brain machine interfaces, cochlear implants, and deep brain stimulation. Students graduating from this emphasis area will be highly qualified for medical school, graduate school, or working in the burgeoning medical device industry dedicated to neural engineering.

It is necessary that the engineering and science elective (ESE) courses be technically coherent and that the courses be mainly in engineering and at an advanced level. In terms of specific requirements: 1. A specific sub-plan (which includes the option of developing a custom sub-plan) must be declared. 2. A maximum of 13 credits of pure science may be counted toward the total. The remaining 14 or more credits must be in engineering or in technical courses (i.e. courses offered through science and medical departments/programs) having significant engineering content, as determined by the appropriate Sub-Plan Advisor (SPA) in consultation with the Director of Undergraduate Studies (DUS) using the definition of engineering credits. The definition of engineering credits is: a. Any course offered by an engineering program, or b. Any course (or course component) that teaches students how to practically apply the knowledge of pure sciences. Students must consult the DUS about the number of engineering credits allowed for such courses. 3. A maximum of 4 credits of 1000 and 2000 level courses may be counted toward the total. 4. A minimum of 19 credits at the 4000 level or higher. 5. A maximum of 6 credits of Directed Research, Directed Study, and/or Industrial Assignment (co-op) may be counted toward the total, and no more than 4 credits of Directed Study may be counted toward the total. Below is a list of suggested courses for your sub-plan. Upon entry to BME upper-division, students will be required to attend an information session and will be provided with additional resources/instructions which will further assist with selecting a course plan from the below list.

Students should review the course descriptions and select an appropriate set of courses consistent with the degree requirements. Students should then enter the selected courses on the Engineering and Science Elective (ESE) Planning Worksheet and schedule a meeting with the appropriate Sub-Plan Advisor (SPA). Students should discuss their ESE course plans and obtain the signature/approval of the appropriate SPA on the ESE worksheet before submitting it to the Director of Undergraduate Studies (DUS) for departmental signature/approval. Department signature/approval of the ESE plan is required for graduation. Changes to the plan must be re-signed/re-approved by the SPA and DUS. It is important to note that the list below is not definitive. Should you find a course that is not listed below that you feel would be beneficial to your ESE course plan, you can present it to SPA and get their approval to count said course towards your ESE requirements. All students must meet with their SPA to get approval on their first ESE worksheet. Thereafter, changes to your ESE course plan can be approved via SPA signature (meeting not required but is encouraged).

Neural Engineering

Take 7 or more course(s) totaling 27 or more credit(s) from the following:

Engineering

Take 14 or more credit(s) from the following:
- BMEN 5411 - Neural Engineering (3.0 cr)
- BMEN 5413 - Neural Decoding and Interfacing (3.0 cr)
- BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
- BMEN 5351 - Cell Engineering (3.0 cr)
- BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
- BMEN 5421 - Introduction to Biomedical Optics (3.0 cr)
- EE 3115 - Analog Electronics (3.0 cr)
- EE 4111 - Advanced Analog Electronics Design (4.0 cr)
- EE 4231 - Linear Control Systems: Designed by Input/Output Methods (3.0 cr)
- EE 4541 - Digital Signal Processing (3.0 cr)
- EE 5545 - Digital Signal Processing Design (3.0 cr)
- BMEN 4011 - CAD/CAE of Bioelectrical Devices (1.0 cr)
- BMEN 4013 - CAD of Biomechanical/transport Devices (1.0 cr)
- BMEN 4015 - CAE of Biomechanical/Transport Devices (1.0 cr)
- BMEN 4896 - Industrial Assignment I: Co-op Program (2.0 cr)
- BMEN 4996W - Industrial Assignment II: Co-op Program [WI] (4.0 cr)
- BMEN 4793 - Directed Study (1.0 - 4.0 cr)
- BMEN 4794 - Directed Research (1.0 - 4.0 cr)
- BMEN 4794H - Directed Research Honors (1.0 - 4.0 cr)

- **Science**

Take 0 or more credit(s) from the following:
- MATH 5447 - Theoretical Neuroscience (4.0 cr)
- CPMS 5101 - Introduction to Clinical Physiology and Movement Science (3.0 cr)
- NSCI 1001 - Fundamental Neuroscience: Understanding Ourselves [TS] (3.0 cr)
- NSCI 3101 - Neurobiology I: Molecules, Cells, and Systems (3.0 cr)
- NSCI 3102W - Neurobiology II: Perception and Behavior [WI] (3.0 cr)
- NSCI 4105 - Neurobiology Laboratory I (3.0 cr)
- RSC 5106 - Introduction to Rehabilitation Science (1.0 cr)
- PHSL 5201 - Computational Neuroscience I: Membranes and Channels (3.0 cr)

Custom Sub-Plan

Biomedical engineering (BME) encompasses a broad range of approaches to improving health through technology. To function as a biomedical engineer, it is important to go beyond a broad training in the core principles of BME to also gain a depth of expertise in one or more specialized areas of BME. To facilitate this, the department requires that 27 credits of advanced engineering and science coursework be completed beyond that in the core curriculum. These advanced courses have a coherent theme and meet the requirements specified in the "degree requirements" section. Because BME is a rapidly evolving field, it is important that the areas of emphasis not be rigidly codified, but rather that students be allowed to customize their advanced studies to suit their own particular interests. Thus, if students do not choose one of our predefined emphasis areas, they are able to work with the Director of Undergraduate Studies to create a customized course list for their area of interest.

It is necessary that the engineering and science elective (ESE) courses be technically coherent and that the courses be mainly in engineering and at an advanced level. In terms of specific requirements: 1. A specific sub-plan (which includes the option of developing a custom sub-plan) must be declared. 2. A maximum of 13 credits of pure science may be counted toward the total. The remaining 14 or more credits must be in engineering or in technical courses (i.e. courses offered through science and medical departments/programs) having significant engineering content, as determined by the appropriate Sub-Plan Advisor (SPA) in consultation with the Director of Undergraduate Studies (DUS) using the definition of engineering credits. The definition of engineering credits is: a. Any course offered by an engineering program, or b. Any course (or course component) that teaches students how to practically apply the knowledge of pure sciences. Students must consult the DUS about the number of engineering credits allowed for such courses. 3. A maximum of 4 credits of 1000 and 2000 level courses may be counted toward the total. 4. A minimum of 19 credits at the 4000 level or higher. 5. A maximum of 6 credits of Directed Research, Directed Study, and/or Industrial Assignment (co-op) may be counted toward the total, and no more than 4 credits of Directed Study may be counted toward the total.

Custom Sub-Plan

In rare instances, students may work with the director of undergraduate studies to create a customized sub-plan for their area of interest consistent with the requirements. Then, students must follow the department's approval process before registering for their coursework.

Take 0 or more course(s) totaling 0 or more credit(s) from the following: