Bachelor of Science in Biomedical Engineering

Integrated Curriculum

BIOMEDICAL ENGINEERING at the UNIVERSITY of VIRGINIA
### Planning Chart

<table>
<thead>
<tr>
<th>Eighth Semester</th>
<th>Fall Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>BME 4064</td>
<td>STS 4600</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Seventh Semester</th>
<th>Fall Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>BME 4063</td>
<td>STS 4500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sixth Semester</th>
<th>Spring Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>BME 3090</td>
<td>BME ___</td>
</tr>
<tr>
<td></td>
<td>BME2102</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fifth Semester</th>
<th>Fall Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>BME 3080</td>
<td>BME ___</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fourth Semester</th>
<th>Spring Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BME 2xxx</td>
<td>BME 2xxx</td>
</tr>
<tr>
<td>BME 2xxx or Prob/Stat</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Third Semester</th>
<th>Fall Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BME 2xxx</td>
<td>BME 2xxx</td>
</tr>
<tr>
<td>BME 2xxx or Prob/Stat</td>
<td>PHYS 2415</td>
</tr>
<tr>
<td></td>
<td>PHYS 2419</td>
</tr>
<tr>
<td></td>
<td>APMA 2130</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Semester</th>
<th>Spring Year 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intro CS CS 111x</td>
<td>PHYS 1425</td>
</tr>
<tr>
<td>You might choose: CS 1113 #300</td>
<td>PHYS 1429</td>
</tr>
<tr>
<td></td>
<td>APMA 2120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>First Semester</th>
<th>Fall Year 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 1610</td>
<td>CHEM 1611</td>
</tr>
<tr>
<td>ENGR 1620</td>
<td>STS 1500</td>
</tr>
<tr>
<td></td>
<td>APMA 1110</td>
</tr>
</tbody>
</table>

### Engineering Core (37 credits)
- APMA 1110 Calculus I
- APMA 2120 Multivariate
- APMA 2130 Ordinary Diff Equations
- CHEM 1610 Intro Chem
- CHEM 1611 Intro Chem Lab
- Science Elec I
- PHYS 1425 Intro Physics I
- PHYS 1429 Intro Physics I Workshop
- PHYS 2415 Intro Physics II
- PHYS 2419 Intro Physics II Workshop
- ENGR 1620 Intro to Engineering
- CS 1110 Intro Computer Science
- APMA 3100 or 3110 Prob or Prob/Stat

*APMA 1090 is an unrestricted elective

### STS (12 credits)
- STS 1500 Lang & the Tech Society
- STS Elective
- STS 4500 Tech & Culture
- STS 4600 Ethics & Society

### Engineering & Technical (9 credits)
- Engr Elective
- Engr Elective
- Tech Elective

### HSS & Unrestricted (21 credits)
- HSS
- HSS
- Unrestricted
- Unrestricted
- Unrestricted
- Unrestricted

### BME (47 credits)
- BME 2000 Intro to BME
- BME 2101 Physiology I
- BME 2102 Physiology II
- BME 2104 Cell & Molecular Biology
- BME 2220 Biomechanics
- BME 2315 Computational BME
- BME 3080 IDEAS Lab I
- BME 3090 IDEAS Lab II
- BME 3240 Biotransport
- BME 3310 BME Systems Analysis
- BME 4063 Capstone Design I
- BME 4064 Capstone Design II
- BME Elective
- BME Elective
- BME Elective
**Variation #1: PREMED**

Our curriculum in BME often bears explaining to medical schools. Here’s what you should do:

Students should ask their “primary” recommendation writer from among the BME faculty to include, as a part of his or her overall letter, the “BME boilerplate text” covering the English composition requirements and Biology requirements. It is the responsibility of the student to make sure that the BME faculty member understands that they should append the boilerplate text, and to ensure that it is appended to only one of the letters they’ve requested. kitter@virginia.edu with any questions!

---

Be sure to contact
Office of PreProfessional Services
Bryant Hall @ Scott Stadium
924-8900,
careercenter@virginia.edu
https://career.virginia.edu/pre-health

Attend open office hours or schedule an individual advising appointment.

**PreMed Requirements:**

2 semesters Chemistry Lecture & Lab. Fulfilled by CHEM 1610, 1611 and CHEM 1620, 1621 (use your Science Elective I).

2 semesters Physics Lecture & Lab. Fulfilled by PHYS 1425, 1429, 2415, 2419.

2 semesters Organic Chemistry Lecture & Lab. Fulfilled by CHEM 2410, 2411, 2420, 2421 (use 1 technical and 3 unrestricted electives).

2 semesters Biology Lecture & Lab. Most medical schools will accept BME 2101, 2102, 2104, 3080, 3090 as a substitute for BIOL 2010-2040. Talk with your BME advisor and the premed advisor about whether or not this is the right decision for your situation.

One semester each: Introductory Psychology and Introductory Sociology. New requirement for the 2015 MCAT Fulfilled by PSYC 1010 and SOC 1010 (HSS elective requirements).

About 1/3 of U.S. medical schools require one or two semesters of math; a few specify that it must be Calculus.

About 2/3 of U.S. medical schools require one or two English classes; for most schools, your STS courses will fulfill this requirement.

---

**When should BMEs take Orgo and MCAT?** BME recommends that you take MCAT soon after completing the courses that are most relevant to the exam, namely: General Chemistry, Organic Chemistry lecture, Physics, Psychology and Sociology, and BME 2101, 2102, and 2104. In the schedule above, we recommend taking the Orgo lectures in 2nd year and preparing for and taking MCAT as soon as possible thereafter. The Orgo Labs can be taken any time before graduation, including during the summer. In the end, how you schedule these courses and the MCAT is a personal decision based on a number of factors, including AP credits/advanced standing, GPA and comfort level taking 5 technical courses in the same semester. Consider the advice of your academic advisor, research mentor, and/or more senior BMEs.
HSS Electives

HSS Electives
9 credits

Chosen from the SEAS Undergraduate Dean’s Office list of approved HSS Electives, available online and in Thornton A-122 (and copied here). Courses that instill cultural values are acceptable while skill development courses are not. Consequently, courses that involve performance must be accompanied by theory or history of the subject. Courses on communication in the student’s native language, regardless of their level, may not be used to satisfy this requirement.

HSS Elective Requirements

a. Instructional categories generally acceptable for HSS elective credit. A student may normally take any course under any one of these categories, with the exception of those listed under b.

HUMANITIES ELECTIVES
Fine Arts
Arth - Architectural History
Arth - Art History
CCFA - Common Course Fine Arts
MDST - Media Studies
Mus - Music General
PLPT - Political Theory
STS - Science, Technology, and Contemporary Issues

History
HIAF - African History
HIEA - East Asian History
HIEU - European History
HILA - Latin American History
HIME - Middle Eastern History
HISA - South Asian History
HIST - General History
HIUS - United States History

Languages
AMTR - Asian and Middle Eastern Language & Culture in Translation
ARAB - Arabic
ARTR - Arabic in Translation
ASL - American Sign Language
BENG - Bengali
CHIN - Chinese

SCIENCE ELECTIVES
Chemistry
Biochemistry
Biology
Botany
Microbiology
Biomedical Engineering
Mathematics

Cultural Anthropology

Religious Studies

Sociology

History

HIAF - African History
HIEA - East Asian History
HIEU - European History
HILA - Latin American History
HIME - Middle Eastern History
HISA - South Asian History
HIST - General History
HIUS - United States History

Languages
AMTR - Asian and Middle Eastern Language & Culture in Translation
Arabic
Arabic in Translation
ASL - American Sign Language
Bengali
Chinese

SOLO SCIENCES ELECTIVES

ANTR - Anthropology
CSSS - Common Course Social Science

SOCIAL SCIENCES ELECTIVES

AAS - African American Studies
AMEL - Asian and Middle Eastern Language & Culture
AMST - American Studies
ANTH - Anthropology
CSSS - Common Course Social Science

*may not offered every semester.

b. Exceptions to 2.a., i.e., courses in the acceptable categories that are NOT suitable for HSS elective credit, generally because of their specialized nature for majors in that field or because they are predominantly skills courses.

- ANTH: 1090, 3810, 3820, 4991, 4993, 4998, 4999, 5080, 5800, 5870, 5880, 5989
- ECON: 3710, 3720, 4010, 4350, 4710, 5090, 5100
- ENSP: 1600
- GDS: 1100, 4951, 4952
- MUSI: 1310, 1993, 2993, 3110, 3320, 3360, 3390, 3993, 4575
- PSYC: 2200, 2210, 2220, 2302, 3005, 3006, 3210, 3870, 3590, 4111, 4125, 4200, 4290, 4330, 4500, 4910, 4970, 4930, 4940, 4980, 5200, 5210, 5260, 5330, 5350, 5401
- SOC: 4800, 4810, 4820, 4970, 5100, 5110, 5120, 5595, 5596
- STS: 4110

ENNC - 19th Century British Literature
ENRN - Renaissance Literature
ENWS - Special Topics in Literature
ENWR - English Writing
Moral, Philosophical, & Religious Perspectives
PHIL - Philosophy
REL - Asian Religious Studies
REL - Christian Studies
REL - General Religious
RELH - Hindu
RELI - Islam
RELI - Judaism
REL - Special Topic in Religion
Technical Electives

3 credits

Chosen from any 2000-level or higher math, science, or engineering course, unless it is a course for non-science majors, it duplicates required BME class work, or it is a “research-for-credit” or capstone design course.

The list on page 8 (this page) shows all the courses that will not count as either a technical or an engineering elective in the BME Major.

Courses that do NOT count as Technical or Engineering electives:

| ASTR 3410  | CS 4980  | EVSC 5031  | PSYC 2150 |
| ASTR 3420  | CS 4998  |          | PSYC 2210 |
| ASTR 3460  | ECE 3750* (due to overlap with BME 3310) | MATH 2310 | PSYC 2300-3110 |
| ASTR 3470  | ECE 4907  | MATH 3100 | PSYC 3410-4180 |
| ASTR 3480  | ECE 4908  | MATH 3120 | PSYC 4300-5200 |
| ASTR 4998  |          | MATH 3250 | PSYC 5260 |
| BIOL 2900  | ENGR 4880 | MATH 3255 | PSYC 5310 |
| BIOL 3000  | ENGR 4890 |          | PSYC 5320 |
| BIOL 3200  | ENGR 4920 |          | PSYC 5500-5650 |
| BIOL 4900  |          |          |          |
| BIOL 4910  | MAE 4511  |          |          |
| BIOL 4920  | MAE 4512  |          |          |
|            | MAE 4513  |          |          |
|            | MAE 4514  |          |          |
| BME 4995   |          |          |          |
| CHE 2246* (due to overlap with BME 2104) | CHE 4995 | CHE 4995 |                  |
| CHEM 3910  | EVSC 2010 | PHYS 2010 |
| CHEM 3920  | EVSC 2900 | PHYS 2020 |
| CHEM 3951  | EVSC 2050 | PHYS 2030 |
| CHEM 3961  | EVSC 2220 | PHYS 2040 |
| CHEM 4951  | EVSC 2030 | PHYS 2360 |
| CHEM 4961  | EVSC 3020 | PHYS 2640 |
| CE 4991    | EVSC 4030 | PHYS 2310 |
| CE 4995    | EVSC 4040 | PHYS 2320 |
|            | EVSC 4050 | PHYS 2660 |
|            | EVSC 4070 | PHYS 3040 |
| CS 4970    | EVSC 4995 | PSYC 2100 |
| CS 4971    | EVSC 5030 |          |          |
**Engineering Electives**

**6 Credits**

Chosen from any 2000-level or higher engineering course, with the following exceptions: no course in APMA, STS, or ENGR may be used as an engineering elective; no course that counts as a Science Elective may be used as an engineering elective; and no course that fulfills the Engineering Business Minor may be used as an engineering elective. Additionally, if course does not count as a technical elective (see page 8), it will not count as an engineering elective. This includes research-for-credit and capstone design courses.

You may use BME courses as engineering electives, but your advisor may encourage you to look outside BME. Due to demand, you may need to be registered as a minor in a given program, to be eligible to enroll in that program’s classes. Plan ahead!

These **SEAS** courses will not count as Engineering Electives:

<table>
<thead>
<tr>
<th>BME 4995</th>
<th>ECE 2066</th>
<th>SYS 4044</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO APMA</td>
<td>ECE 3750</td>
<td>SYS 5044</td>
</tr>
<tr>
<td>NO STS</td>
<td>ECE 4907</td>
<td>SYS 4995</td>
</tr>
<tr>
<td>NO ENGR</td>
<td>ECE 4908</td>
<td>SYS 3055</td>
</tr>
<tr>
<td>BME 4995</td>
<td>ECE 4991</td>
<td>SYS 4053</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SYS 4054</td>
</tr>
<tr>
<td>CHE 2246</td>
<td>MAE 4511</td>
<td>SYS 4055</td>
</tr>
<tr>
<td>CHE 4995</td>
<td>MAE 4512</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAE 4513</td>
<td></td>
</tr>
<tr>
<td>CE 4000</td>
<td>MAE 4514</td>
<td></td>
</tr>
<tr>
<td>CE 4500</td>
<td>MAE 4990</td>
<td></td>
</tr>
<tr>
<td>CE 4990</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE 4991</td>
<td>MSE 2010</td>
<td></td>
</tr>
<tr>
<td>CE 4995</td>
<td>MSE 2090</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MSE 4960</td>
<td></td>
</tr>
<tr>
<td>CS 4753</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS 4970</td>
<td>SYS 2055</td>
<td></td>
</tr>
<tr>
<td>CS 4971</td>
<td>SYS 2056</td>
<td></td>
</tr>
<tr>
<td>CS 4980</td>
<td>SYS 2057</td>
<td></td>
</tr>
<tr>
<td>CS 4993</td>
<td>SYS 4000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYS 2620</td>
<td></td>
</tr>
</tbody>
</table>
BME Electives

9 Credits

Chosen from any 3000-level or higher BME elective. One of the following non-BME courses may be included as a BME elective: CHE 3347, CHE 4448, or ECE 4750. Only 3 credits of BME 4995 may be used as a BME Elective.

Recent BME Electives

**BME 4414 Biomaterials.** Lawrence.  
Prerequisite: BME 2101, BME 2104 or CHE 2246, 3rd or 4th year standing, or instructor permission.

**BME 4641 Bioelectricity.** Helmke.  
Prerequisite: BME 3310 or ECE 2630, and BME 2101, or instructor permission.

**BME 4890 Nanomedicine.** Kelly.  
Prerequisite: BME 2104 or CHE 2246, BME 2220, 4th year standing, or instructor permission.

**BME 4280 Motion Biomechanics.** Blemker.  
Prerequisite: BME 2101, BME 2220, or instructor permission.

**BME 4417 Tissue Engineering.** Munson.  
Prerequisite: APMA 2130, BME 2101, BME 2104 or instructor permission.

**BME 4783 Medical Imaging Modalities.** Hossack/Epstein. Prerequisites: BME 2101 and BME 3310.

**BME 4806 Biomedical Applications of Genetic Engineering.** French. Prerequisite: BME 2101, BME 2102, BME 2104 or CHE 2246, and 3rd/4th year standing, or instructor permission.

**BME 3030 Design and Innovation in Medicine.** Allen and Chen. Prerequisite: BME 2000 and instructor permission.

**BME 4995 BME Advanced Projects.** Varies.  
Prerequisite: instructor permission and approval of the BME Undergraduate Program Director. Only 3 credits (total) of BME 4995-454 will count as BME elective. Another 3 credits will count as an Unrestricted elective.

**BME 4550 Special Topics in Biomedical Engineering.** Prerequisite: 3rd or 4th year standing or instructor permission.

**BME 4550 Systems Bioengineering Modeling and Experimentation.** Allen et al.

**BME 4550 Quantitative Biological Reasoning.** Janes.

**BME 4550 Nanomedicine Lab.** Helmke adn Lawrence.

**BME 4550 BME Data Science.** Civelek.

**BME 4550 Microbial BME.** Papin.

**BME 4550 Rehabilitation Engineering.** Chen. Prerequisite: Instructor permission.

**BME 4993 Independent Study.**  
Prerequisite: Instructor permission and approval of the Undergrad Program Director.

May I use a graduate level BME course as “BME” Electives? Yes, with instructor permission. The instructor will need to add you to his course roll in the SIS and you may need to fill a Dean’s Office form called “Undergraduate Request to Take Graduate Courses.”
What is an “Optional Bioengineering Focus Area?”
You have quite a few elective “buckets” to fill in the BME major (technical, engineering, BME, unrestricted, etc). One strategy is to use these electives to build depth in a certain focus area. This list will help you to do so.

Is this required?
No - it’s optional!

Do I take every class listed in a certain focus area?
No. The list is a guide.

Optional Bioengineering Focus Areas

This is an optional advising tool to help you build depth in a relevant area. Prerequisites are in parentheses.

Biomaterials and Regenerative Medicine
- MSE 2090 Intro to the Science and Engineering of Materials
- CHE 4449 Polymer Chemistry and Engineering (inst. permission)
- BME 4414 Biomaterials
- BME 4417 Tissue Engineering

Pharmaceutical Biotechnology
- CHE 2215 Material and Energy Balances
- CHE 3321 Transport Processes I (CHE 2215)
- CHE 3347 Biochemical Engineering (CHE 3321)
- CHE 4442 Applied Surface Chemistry
- BME 4890 Nanomedicine
- BME 4550 Systems Bioengineering Modeling and Experimentation

Computational Systems Bioengineering
- SYS 3021 Deterministic Decision Models (SYS 2001)
- CS 2102 Discrete Mathematics I (CS 2110)
- BIOL 4160 Functional Genomics (Inst. permission)
- APMA 3080 Linear Algebra
- BME 4550 Systems Bioengineering Modeling and Experimentation

Biomedical Software
- CS 2110 Software Development Methods
- CS 2102 Discrete Mathematics I (CS 2110)
- CS 2150 Program and Data Representation (CS 2110, 2102)
- CS 3240 Advanced Software development Techniques (CS 2150)

Muscloskeletal Biomechanics
- MAE/CE 2300 Statics
- MAE/CE 2310 Strength of Materials (MAE 2300)
- MAE 2320 Dynamics (MAE 2300)
- BME 4280 Motion Biomechanics

Neural Systems Engineering
- ECE 2630 Introductory Circuit Analysis
- ECE 3630 Electronics I (ECE 2630)
- BIOL 3170 Neurobiology
- BME 3636 Neural Network Models
- BME 4641 Bioelectricity

Entrepreneurship
- BME 4550 Spc Tpc BME Advanced Design
- CS 4753, CE 4000, SYS 4044, SYS 5044

Bioinstrumentation
- ECE 2630 Intro to Circuits
- ECE 3630 Electronics I (ECE 2630)
- ECE 2330 Digital Logic Design
- ECE 3760 Signals and Systems II (ECE 2630, BME 3310)
- ECE 3632 Electronics II (ECE 3630)

Signal Processing
- ECE 2630 Intro Circuit Analysis
- ECE 3760 Signals and Systems II (ECE 2630, BME 3310)
- ECE 2066 Science of Information
- ECE 5750 Digital Signal Processing (ECE 3750 or BME 3310, ECE 3760)

Biomedical Imaging (see page 51)
- ECE 2630 Intro Circuit Analysis
- ECE 3760 Signals & Systems II (ECE 2630, ECE 3750 or BME 3310)
- ECE 5750 Digital Signal Processing (ECE 3750 or BME 3310, ECE 3760)
- Graduate-level BME imaging courses, as appropriate
- ECE 6782 Digital Image Processing

Clinical Applications in Biomedical Engineering
- MAE 2300 Statics
- BIOL 5010 Biochemistry (prereq organic chemistry)
- Advanced Biology course, as appropriate, such as BIOL 3080, BIOL 3090, BIOL 3140, BIOL 3240
- BME 4414 Biomaterials
- BME 4280 Motion Biomechanics

Nanomedicine Engineering
- BME 4890 Nanomedicine Engineering
- MSE 4055 Nanoscale Science and Technology (MSE 3670, PHYS 2320, PHYS 2620, or CHEM 3410 or CHEM 3820)
- Physical Chemistry (Organic Chemistry)
- BME 4414 Biomaterials
## Course Descriptions: BME 2000-3090

### BME 2000 - (3) REQUIRED, Spring
**Intro to BME Design & Discovery**
Prerequisite: CS 1110, PHYS 1425, and ENGR 1620, or instructor permission. Covers conceptual and detail design processes and the special challenges inherent to biomedical devices. Students will formulate and execute a major, semester-long design project.

### BME 2101 - (3) REQUIRED, Fall
**Physiology for Engineers I**
Prerequisite: CHEM 1610, and PHYS 1425, or instructor permission. Studies how excitable tissue, nerves and muscle, and the cardiovascular and respiratory systems work. Focuses on understanding mechanisms and includes an intro to structure, an emphasis on quantitative function, and integration of hormonal and neural regulation and control.

### BME 2102 - (3) REQUIRED, Spring
**Physiology for Engineers II**
Prerequisite: BME 2101, or instructor permission. Introduces the physiology of the kidney, salt and water balance, gastrointestinal system, endocrine system, and central nervous system, with reference to diseases and their pathophysiology.

### BME 2104 - (3) REQUIRED, Spring
**Cell & Molecular Biology for Engineers**
Prerequisite: CHEM 1610 and BIOL 2101, or instructor permission. Introduces the fundamentals of cell structure and function, emphasizing the techniques and technologies available for the study of cell biology. A problem-based approach is used to motivate each topic. Divided into three general sections: cell structure and function includes cell chemistry, organelles, enzymes, membranes, membrane transport, intracellular compartments and adhesion structures; energy flow in cells concentrates on the pathways of glycolysis and aerobic respiration; information flow in cells focuses on modern molecular biology and genetic engineering, and includes DNA replication, the cell cycle, gene expression, gene regulation, and protein synthesis. Also presents specific cell functions, including movement, the cytoskeleton and signal transduction. Students may not receive credit for both CHE 2246 and BME 2104.

### BME 2220 - (3) REQUIRED, Spring
**Biomechanics**
Prerequisite: APMA 2120, 2130, and BME 2101, or instructor permission. Introduces the principles of continuum mechanics of biological tissues and systems. Topics include 1) review of selected results from statics and strength of materials, continuum mechanics, free-body diagrams, constitutive equations of biological materials, viscoelastic models, and fundamental concepts of fluid mechanics and mass transport; 2) properties of living tissue; 3) mechanical basis and effects of pathology and trauma, 4) introduction to mechanotransduction, circulatory transport, growth and remodeling, and tissue-engineered materials, and 5) low Reynolds number flows in vivo and in microsystems.

### BME 2240 - (3) REQUIRED, Spring
**Biotransport**
Prerequisite: APMA 2120, 213, BME 2101, 2104 or equivalent, or instructor permission. Biotransport in biological living systems is a fundamental phenomenon important in all aspects of the life cycle. Course will introduce principles and application of fluid and mass transport processes in cell, tissue and organ systems. Topics include introduction to physiological fluid mechanics in the circulation and tissue, fundamentals of mass transport in biological systems, effects of mass transport and biochemical interactions at the cell and tissue scales, and fluid and mass transport in organs.

### BME 3310 - (3) REQUIRED, Fall
**Biomedical Systems Analysis & Design**
Prerequisites: APMA 2130, CS 1110, and PHYS 1425, or instructor permission. Presents the analytical tools used to model signals and linear systems. Specific biomedical engineering examples include multicompartiment modeling of drug delivery, modeling of dynamic biomechanical systems, and electrical circuit models of excitable cells. Major topics include terminology for signals and systems, convolution, continuous time Fourier transforms, electrical circuits with applications to bioinstrumentation and biosystems modeling, and applications of linear system theory. Students may not receive credit for both ECE 3750 and BME 3310.

### BME 3315 - (3) REQUIRED, Fall
**Computational BME**
Prerequisite: BME 2101, 2104, and 2220, or instructor permission. Introduces techniques for constructing predictive or analytical engineering models for biological processes. Teaches modeling approaches using example problems in transport, mechanics, bioelectricity, molecular dynamics, tissue assembly, and imaging. Problem sets will include 1) linear systems and filtering, 2) compartmental modeling, 3) numerical techniques, 4) finite element / finite difference models, and 5) computational automata models.

### BME 3080, 3090 - (4+4) REQUIRED, Fall, Spring
**BME IDEAS Lab I & II**
Prerequisite: BME 2101, 2104, and 2220, and 3rd year standing in the BME major, or Inst. permission. Year-long course to integrate concepts and skills from prior courses in order to formulate and solve problems in biomedical systems, including experimental design, performance, and analysis. Lab modules include testing in tissues/cells and manipulation of molecular constituents of living systems to determine their structural and functional characteristics for design of therapeutic or measurement systems. Methods include biochemical, physiological, cell biology, mechanical, electrical and computer, systems, chemical, imaging, and other approaches.
BME 4063, 4064 - (3+3) REQUIRED, Fall, Spring
Biomedical Engineering Capstone Design I & II
Prerequisite: Fourth year standing in BME major, or instructor permission. A year-long design project in biomedical engineering required for BME majors. Students select, formulate, and solve a design problem related to a device or a system. Projects use conceptual design, skills obtained in the integrated lab, and substantial literature and patent reviews. Projects may be sponsored by BME faculty, medical doctors, and/or companies. Students may work on their own with outside team members when appropriate or with other SEAS students in integrative teams.

BME 4280 - (3) ELECTIVE, Spring
Motion Biomechanics
Prerequisite: BME 2101, 2220, or instructor permission. Focuses on the study of forces (and their effects) that act on the musculoskeletal structures of the human body. Based on the foundations of functional anatomy and engineering mechanics (rigid body and deformable approaches); students are exposed to clinical problems in orthopedics and rehabilitation.

BME 4414 - (3) ELECTIVE, Fall
Biomaterials
Prerequisite: BME 2101, 2104 or equivalent, 3rd or 4th year standing, or instructor permission. This course will provide an introduction to biomaterials science and biological interactions with materials, including an overview of biomaterials testing and characterization. The emphasis of this course, however, will be on emerging novel strategies and design considerations of biomaterials. Areas of concentration will include the use of polymers and ceramics in biomaterials today, drug delivery applications, tissue engineering from both an orthopaedic and vascular perspective, and nanotechnology related to biomaterials. Specific attention will also be paid to the in vitro and in vivo testing of biomaterials, and a review of current research in the field.

BME 4417 - (3) ELECTIVE, Spring
Tissue Engineering
Prerequisite: APMA 2130, BME 2101, and 2104 or equivalent, or instructor permission. Introduces the fundamental principles of tissue engineering. Topics include: tissue organization and dynamics, cell and tissue characterization, cell-matrix interactions, transport processes in engineered tissues, biomaterials and biological interfaces, stem cells and interacting cell fate processes, and tissue engineering methods. Examples of tissue engineering approaches for regeneration of cartilage, bone, ligament, tendons, skin and liver are presented.

BME 4550 - (3+3) ELECTIVE, Fall, Spring
Special Topics in Biomedical Engineering
Prerequisite: varies. Applies engineering science, design methods, and system analysis to developing areas and current problems in biomedical engineering.

BME 4550 - (3) ELECTIVE, Fall
Systems Bioengineering Modeling and Experimentation
Prerequisite: Fourth year standing in BME major, or instructor permission. Introduces techniques for constructing mathematical and computational models of vascular biological processes and utilizing experimental methods to validate those models at many levels of organizational scale, from genome to whole-tissue. In each of three modules, teams complete group modeling projects that apply the modeling techniques specific to the particular module. Teams will also conduct experiments relevant to the biological question of each module. Topics to be covered include choice of modeling techniques appropriate to addressing particular biological problems at different scales, quantitative characterization of biological properties, assumptions and model simplification, parameter estimation and sensitivity analysis, model verification and validation, and integration of computational modeling with experimental approaches.

BME 4417 - (3) ELECTIVE, Spring
Quantitative Biological Reasoning
Prerequisite: 4th year standing and instructor permission. Provides a quantitative framework for identifying and addressing important biological questions at the molecular, cell, and tissue levels. Covers methods, with an emphasis on the biochemical, biophysical, and mathematical themes that emerge repeatedly in quantitative experiments. Discussions preceded by primary literature that illustrates how in-depth understanding of such themes led to significant conceptual advances in biochemistry, molecular biology, and cell biology. Part II covers how quantitative methods combine to aid scientific logic. Topics include practical implementations of the scientific method, falsification of hypotheses and strong inference. Course concludes with an intro to how quantitative biological reasoning can be effectively presented through scientific writing and information design.
Course Descriptions: **BME 4550-4995**

**BME 4550 - (3) ELECTIVE, Spring**  
**BME Advanced Design**  
Prerequisite: BME 2000 and instructor permission. Project-driven course focusing on biomedical product design, with an emphasis on marketability, innovation, entrepreneurship, and business. Topics covered include design fundamentals, problem/needs identification, delineation of realistic constraints and product specifications, intellectual property, market analysis, entrepreneurship, specific advanced design topics (e.g., design for manufacturing, cradle-to-grave product lifecycle analysis, etc.), business plan development, venture funding, and medical product testing methods.

**BME 4641 - (3) ELECTIVE, Fall**  
**Bioelectricity**  
Prerequisite: BME 3310 or ECE 2630, BME 2101, or instructor permission. Studies the biophysical mechanisms governing production and transmission of bioelectric signals, measurement of these signals and their analysis in basic and clinical electrophysiology. Introduces the principles of design and operation of therapeutic medical devices used in the cardiovascular and nervous systems. Includes membrane potential, action potentials, channels and synaptic transmission, electrodes, electroencephalography, electromyography, electrocardiography, pacemakers, defibrillators, and neural assist devices.

**BME 4783 - (3) ELECTIVE, Spring**  
**Medical Imaging Modalities**  
Prerequisite: BME 3310 or ECE 3750, or instructor permission. An overview of modern medical imaging modalities with regard to the physical basis of image acquisition and methods of image reconstruction. Topics cover the basic engineering and physical principles underlying the major medical imaging modalities: x-ray (plain film, mammography, and CT), nuclear medicine (PET and SPECT), ultrasound, and MRI.

**BME 4806 - (3) ELECTIVE, Spring**  
**Biomedical Applications of Genetic Engineering**  
Prerequisite: BME 2101, 2102, and 2104, and 3rd/4th year standing, or instructor permission. Provides a grounding in molecular biology and a working knowledge of recombinant DNA technology, thus establishing a basis for the evaluation and application of genetic engineering in animal systems. Beginning with the basic principles of genetics, this course examines the use of molecular methods to study gene expression, deliver viral and non-viral vectors, and its critical role in health.

**BME 4890 - (3) ELECTIVE, Fall**  
**Nanomedicine Engineering**  
Prerequisite: BME 2104 or CHE 2246, BME 2220, or 4th year standing, or instructor permission. BME 2240 or CHE 3321 recommended. Students will design treatment strategies for cancer and cardiovascular disease based on molecular bio-engineering principles. Special topics will include design of nanoparticle drug and gene delivery platforms, materials biocompatibility, cancer immunotherapy, and molecular imaging.

**BME 4993 - (1-3) ELECTIVE, Fall, Spring**  
**Independent Study**  
Prerequisite: instructor permission. In-depth study of a biomedical engineering area by an individual student in close collaboration with a departmental faculty member. Requires advanced analysis of a specialized topic in biomedical engineering that is not covered by current offerings. Requires faculty contact time and assignments comparable to regular course offerings. See page 15.

**BME 4995 - (1-3) ELECTIVE, Fall, Spring**  
**BME Advanced Projects**  
Prerequisite: instructor permission and approval of the BME Undergrad Program Director. Use Form on pg 17. Research project in biomedical engineering conducted in consultation with a department faculty advisor, usually related to ongoing faculty research. Includes the design, execution, and analysis of experimental laboratory work and computational or theoretical computer analysis of a problem. Requires a comprehensive report of the results. Only 3 credits of BME 4995 will count as BME elective. Another 3 credits will count as an Unrestricted Elective.
Required Approval Form
BME Independent Study (BME 4993) - 3 credits maximum

Independent Study is an in-depth exploration of a technical area in biomedical engineering for which there is no formal course offering. It exhibits the hallmarks of a formal course offering - e.g. regular and significant faculty contact time, assigned reading, regular homework or projects, and a final exam or paper. Requires approval from the Undergraduate Program Director. Use this form to propose and describe your topic.

- Listed as BME 4993 "BME Independent Study."
- Up to 3 credits of BME 4993 will count as a BME Elective in the BME Major.
- Does NOT count toward the BME Minor.

Procedure:

Your Name: _______________________________________ BME Advisor: _______________

Today’s Date: _____________ Year of Graduation: _______ Your Email: ______________________

1) Instructor information. If the proposed instructor is not a primary BME primary faculty member, see the Undergrad Program Director for special instructions. Instructor’s Name (print): _____________________________

2) Attach a one-page COURSE MEMO. Include 1) a one-paragraph Course Description, 2) Planned Assignments for the semester, 3) Textbook and/or reading list, 4) and Meeting Times and Frequency.

3) SIGNATURES. Have the course instructor sign the Course Memo. Return the signed memo and this form to the BME Undergrad Coordinator, MR5 2010. You will be informed of the success of your petition via email.

Approved: _____________________________________  

BME Undergraduate Program Director
Required Approval Form
Substituting a Core Course / Replacing a Requirement

Procedure: Fill out this form (duplicate if necessary for multiple requests) and return to Undergrad Coordinator in MR5 2010. You will be informed of the success of your petition via email.

Course/Requirement #1
1) What course/requirement would you like to replace? _______________________
2) What would you like to replace it with? _______________________
3) Reason: _______________________

Approved: _______________________
BME Undergraduate Program Director

Course/Requirement #2
1) What course/requirement would you like to replace? _______________________
2) What would you like to replace it with? _______________________
3) Reason: _______________________

Approved: _______________________
BME Undergraduate Program Director
Required Approval Form for BME Advanced Projects (BME 4995, “Research- or Design-for-Credit”)

Consists of the design, execution, and analysis of lab work, computational modeling, or theoretical analysis in a biomedical engineering subject area. Requires a comprehensive final report describing methods and results. You may work with any BME primary faculty member. It is possible to work with non-BME faculty, if a BME primary faculty member agrees to co-advice your project. In this case, the BME faculty member is listed as the course instructor and assigns the grade, in consultation with the research mentor. Under certain circumstances, this rule may be waived. See the Undergrad Coordinator for details.

Use BME 4995 “BME Advanced Projects.” All projects must approved by the Undergraduate Program Director using this form.
- You must submit this form for approval EACH SEMESTER you plan to do research-for-credit (even for a continuing project).
- For each credit hour earned, you must spend at least 3-4 hours per week in the lab, for a minimum of 10 hours/week for 3 credit-hour course.
- Relationship between Advanced Projects & Capstone Projects: Unless the two projects are entirely separate, you may NOT earn credit for BME 4995 at the same time you are earning credit for BME 4063, 4064.
- BME Majors may count up to six credits (total) toward the degree. Three (3) credits can be used as a BME Elective, and the other three (3) credits can be used as an Unrestricted Elective.

Procedure
Your Name: ___________________________ Email: _______________________ Today’s Date: _____________________
Lab Name: ___________________________ Research Advisor’s name (print): ___________________________

If your research advisor is not a primary BME faculty member, which primary BME faculty member is co-advising this project?

Will you be attending lab meetings? (circle one) Yes No If no, why not? ____________________________________

1) Attach a PROJECT PROPOSAL (half-page). The proposal should include i) Project Title and Study Name (more specific than title), ii) Purpose/Objective of your proposed project, iii) your Hypothesis (if applicable), iv) the Experimental Design (i.e. experimental conditions and measurable output), v) your Methods, and vi) the Significance of your research (what is the impact of your results in the field?)

2) Attach a PROJECT EXPECTATIONS STATEMENT (one paragraph). Here you describe the project guidelines worked out between you, your research mentor, and (if applicable) the BME primary faculty member co-advising your project. You must cover i) Days and times you are scheduled to work in the lab, ii) How often you will be meeting with your research mentor, iii) When your final report is due and iv) Other expectations, including required background literature, monthly progress reports, etc. If you are working in a non-BME lab, you must also report how often you plan to meet with your BME primary advisor.

3) SIGNATURES. Both you and your Research Advisor must sign the Project Proposal / Expectations Statement. If you plan to work in a non-BME lab, your BME primary advisor must sign, too. Return this form and the signed Project Proposal / Expectations Statement to the Undergraduate Coordinator (MR5 2010). You will be informed of the success of your petition via email.

Approved: __________________________________

BME Undergraduate Program Director