BIOMETICAL ENGINEERING, BACHELOR OF SCIENCE (B.S.)

Biomedical engineering applies engineering expertise to analyze and solve problems in biology and medicine in order to enhance health care. Students involved in biomedical engineering learn to work with living systems and to apply advanced technology to the complex problems of medical care. Biomedical engineers work with other health care professionals including physicians, nurses, therapists and technicians toward improvements in diagnostic, therapeutic and health delivery systems. Biomedical engineers may be involved with designing medical instruments and devices, developing medical software, tissue and cellular engineering, developing new procedures or conducting state-of-the-art research needed to solve clinical problems.

There are numerous areas of specialization and course work within biomedical engineering. These include:

1. Bioinstrumentation: the application of electronics and measurement techniques to develop devices used in the diagnosis and treatment of disease, including heart monitors, intensive care equipment, cardiac pacemakers and many other electronic devices.
2. Biomaterials: the development of artificial and living materials used for implantation in the human body, including those used for artificial heart valves, kidney dialysis cartridges, and artificial arteries, hips and knees.
3. Biomechanics: the study of motion, forces and deformations in the human body, including the study of blood flow and arterial disease, forces associated with broken bones and their associated repair mechanisms, mechanisms of blunt trauma including head injuries, orthopedic systems, and the forces and movement associated with human joints such as the knee and hip.
4. Tissue and cellular engineering: the application of biochemistry, biophysics and biotechnology toward the development of new cellular and tissue systems and an understanding of disease processes, including development of artificial skin and organs, cell adherence to artificial materials to prevent rejection by the body, and the development of new genetic cellular systems to treat diseases.
5. Medical imaging: the development of devices and systems to image the human body to diagnose diseases, including the development and data processing of the CAT scan, MRI (magnetic resonance imaging), medical ultrasound, X-ray and PET (positron emission tomography).
6. Rehabilitation and human factors engineering: the development of devices and prosthetics to enhance the capabilities of disabled individuals, including design of wheelchairs, walkers, artificial legs and arms, enhanced communication aids, and educational tools for people with disabilities.

A unique aspect to the undergraduate biomedical engineering is the practicum series, EGRB 101 and EGRB 301, which involves biomedical engineering students participating in medical rounds at the VCU Medical Center’s MCV Hospitals, in medical research laboratories throughout the medical center and the Virginia BioTechnology Research Park, and in medical seminars, case studies and medical laboratories. This unique opportunity is the only one of its kind in the nation and involves the cooperation of the VCU Medical Center, one of the nation’s largest and most prestigious medical centers.

Learning outcomes

Upon completing this program, students will know and know how to do the following:

- Identify and apply recent knowledge, and analyze and solve problems in the foundation areas of mathematics, the sciences and statistics.
- Identify and apply recent knowledge, and analyze and solve problems in the foundation engineering areas of electrical circuits, mechanics, biomedical engineering, and engineering systems and design.
- Identify and apply recent knowledge, and analyze and solve problems in the life sciences, including biology, physiology and anatomy, and understand the relationship between the life sciences, mathematics and engineering.
- Design and conduct lab experiments, collect, analyze and interpret data from physical and simulated systems to solve technical problems, and analyze physiology and life science laboratory experiments to integrate engineering and physiology/biology.
- Design and implement a system, component or process to meet the desired needs within a set of realistic specifications and constraints; design systems used in biomedical applications that involve the interconnection between engineering and the life sciences, including issues of health, safety and medical ethics.
- Organize ideas and write well-organized and accurate reports, including appropriate citations; deliver oral presentations to peers and supervisors using the latest presentation technologies.
- Understand the need for the various elements and facets of a career in biomedical engineering and related fields; have a recent understanding of the knowledge tools necessary to achieve lifelong learning and career development.
- Understand the nature of, and have the ability to, function on multidisciplinary and interdisciplinary teams, and understand the role that each team member brings to the overall goal.
- Attain and further master the ability to formulate, analyze and solve problems, analytically and/or experimentally, in biomedical engineering industry, in the clinical setting or in biomedical research within a few years of graduation. The career paths of BME graduates in these arenas would be enhanced as a result of these skills.
- Attain and further master the ability to understand the life and health sciences and the interconnection between engineering and the life/health sciences including biology, anatomy, physiology and biomedical engineering, with particular reference to biomedical engineering industry, in the clinical setting or in biomedical research within a few years of graduation. The career paths of BME graduates in these arenas would be enhanced as a result of these skills.
- Attain and further master the ability to articulate ideas and communicate in a clear and effective manner appropriate to their audience, in both written and and/or oral forms, with particular reference to biomedical engineering industry, in the clinical setting or in biomedical research within a few years of graduation. The career paths of BME graduates in these arenas would be enhanced as a result of these skills.
- Attain and further master the ability to work effectively in teams to solve biomedical and/or clinical problems, including the interconnection of engineering and clinical personnel toward the solution of problems of compelling clinical and biomedical interest and need, with particular reference to biomedical engineering industry, in the clinical setting or in biomedical research within a few years of graduation. The career paths of BME graduates in these arenas would be enhanced as a result of these skills.
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### Degree requirements for Biomedical Engineering, Bachelor of Science (B.S.)

#### General Education requirements

**University Core Education Curriculum**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIV 111</td>
<td>Play course video for Focused Inquiry I</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 112</td>
<td>Play course video for Focused Inquiry II</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 200</td>
<td>Inquiry and the Craft of Argument</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Approved humanities/fine arts</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Approved natural/physical sciences</td>
<td>3-4</td>
</tr>
<tr>
<td></td>
<td>Approved quantitative literacy</td>
<td>3-4</td>
</tr>
<tr>
<td></td>
<td>Approved social/behavioral sciences</td>
<td>3-4</td>
</tr>
</tbody>
</table>

#### General Education requirements

- **PHYS 207**: University Physics I – 5
- **PHYS 208**: University Physics II – 5

| Total Hours | 31-34 |

#### Collateral requirements

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 151</td>
<td>Introduction to Biological Sciences I</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 101</td>
<td>General Chemistry I</td>
<td>4</td>
</tr>
<tr>
<td>&amp; CHEZ 101</td>
<td>and General Chemistry Laboratory I</td>
<td>4</td>
</tr>
<tr>
<td>CHEM 102</td>
<td>General Chemistry II</td>
<td>4</td>
</tr>
<tr>
<td>&amp; CHEZ 102</td>
<td>and General Chemistry Laboratory II</td>
<td>4</td>
</tr>
<tr>
<td>MATH 200</td>
<td>Calculus with Analytic Geometry (fulfills approved quantitative literacy)</td>
<td>4</td>
</tr>
<tr>
<td>MATH 201</td>
<td>Calculus with Analytic Geometry</td>
<td>4</td>
</tr>
<tr>
<td>MATH 301</td>
<td>Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>MATH 310</td>
<td>Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td>PHIL 201</td>
<td>Critical Thinking About Moral Problems (fulfills approved humanities/fine arts)</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 207</td>
<td>University Physics I (fulfills General Education requirement)</td>
<td>5</td>
</tr>
<tr>
<td>PHYS 208</td>
<td>University Physics II (fulfills General Education requirement)</td>
<td>5</td>
</tr>
<tr>
<td>STAT 210</td>
<td>Basic Practice of Statistics</td>
<td>3</td>
</tr>
<tr>
<td>or STAT 441</td>
<td>Applied Statistics for Engineers and Scientists</td>
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</tr>
</tbody>
</table>

| Total Hours | 24 |

#### Major requirements

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGRB 101</td>
<td>Biomedical Engineering Practicum I</td>
<td>2</td>
</tr>
<tr>
<td>EGRB 102</td>
<td>Introduction to Engineering</td>
<td>4</td>
</tr>
<tr>
<td>EGRB 203</td>
<td>Statics and Mechanics of Materials</td>
<td>3</td>
</tr>
<tr>
<td>EGRB 215</td>
<td>Computational Methods in Biomedical Engineering I</td>
<td>3</td>
</tr>
<tr>
<td>EGRB 301</td>
<td>Biomedical Engineering Design Practicum</td>
<td>3</td>
</tr>
<tr>
<td>EGRB 303</td>
<td>Biotransport Processes</td>
<td>3</td>
</tr>
<tr>
<td>EGRB 307</td>
<td>Biomedical Instrumentation</td>
<td>4</td>
</tr>
<tr>
<td>EGRB 308</td>
<td>Biomedical Signal Processing</td>
<td>4</td>
</tr>
<tr>
<td>EGRB 310</td>
<td>Biomechanics</td>
<td>4</td>
</tr>
<tr>
<td>EGRB 315</td>
<td>Computational Methods in Biomedical Engineering II</td>
<td>3</td>
</tr>
<tr>
<td>EGRB 401 &amp; EGRB 402</td>
<td>Biomedical Engineering Senior Design Studio &amp; Biomedical Engineering Senior Design Studio</td>
<td>6</td>
</tr>
<tr>
<td>EGRB 427</td>
<td>Biomaterials</td>
<td>3</td>
</tr>
<tr>
<td>EGRE 206</td>
<td>Electric Circuits</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 395</td>
<td>Professional Development</td>
<td>1</td>
</tr>
<tr>
<td>PHIS 309</td>
<td>Introductory Quantitative Physiology I</td>
<td>4</td>
</tr>
</tbody>
</table>

| Total Hours | 51 |

#### Open electives

Approved 200-level or higher open engineering elective or a technical elective course selected from any BME track below. Technical electives within declared track 21

| Total Hours | 24 |

#### Total minimum requirement 131 credits

**Electives**

Biomedical engineering students must select all technical electives from one of the four technical elective tracks.

**Pre-medical track**

- **BIOI 151**: Introduction to Biological Sciences I – 3
- **BIOZ 151**: Introduction to Biological Science Laboratory I – 1
- **BIOZ 152**: Introduction to Biological Sciences II – 3
- **BIOZ 152**: Introduction to Biological Science Laboratory II – 1
- **BIOZ 300**: Cellular and Molecular Biology
- **or BIOZ 310**: Genetics
- **or CHEM 403**: Biochemistry I
- **CHEM 301**: Organic Chemistry – 3
- **CHEZ 301**: Organic Chemistry Laboratory I – 2
- **CHEM 302**: Organic Chemistry – 3
- **CHEZ 302**: Organic Chemistry Laboratory II – 2
- **EGRB 403**: Tissue Engineering
- **or EGRB 410**: Cellular Engineering
- **ENGR 497 or INNO 460**: Vertically Integrated Projects
- **Product Innovation: da Vinci Project**

**Pre-medical track**

| Total Hours | 24 |

**Biomechanics and biomaterials track**

- **EGRB 403**: Tissue Engineering – 3
- **EGRB 405**: Finite Element Analysis in Solid Mechanics – 3
- **EGRB 406**: Artificial Organs – 3
- **EGRB 410**: Cellular Engineering – 3
- **EGRB 411**: Cell Mechanics and Mechanobiology – 3
- **EGRB 412**: Regenerative Engineering and Medicine – 3
- **EGRB 413**: Computational and Experimental Models of Cellular Signal Transduction – 3
- **EGMN 201**: Dynamics and Kinematics – 3

| Total Hours | 3 |

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**Electives**

Biomedical engineering students must select all technical electives from one of the four technical elective tracks.

**Pre-medical track**

- **BIOI 151**: Introduction to Biological Sciences I – 3
- **BIOZ 151**: Introduction to Biological Science Laboratory I – 1
- **BIOZ 152**: Introduction to Biological Sciences II – 3
- **BIOZ 300**: Cellular and Molecular Biology
- **or BIOZ 310**: Genetics
- **or CHEM 403**: Biochemistry I
- **CHEM 301**: Organic Chemistry – 3
- **CHEZ 301**: Organic Chemistry Laboratory I – 2
- **CHEM 302**: Organic Chemistry – 3
- **CHEZ 302**: Organic Chemistry Laboratory II – 2
- **EGRB 403**: Tissue Engineering
- **or EGRB 410**: Cellular Engineering
- **ENGR 497 or INNO 460**: Vertically Integrated Projects
- **Product Innovation: da Vinci Project**

| Total Hours | 24 |

**Biomechanics and biomaterials track**

- **EGRB 403**: Tissue Engineering – 3
- **EGRB 405**: Finite Element Analysis in Solid Mechanics – 3
- **EGRB 406**: Artificial Organs – 3
- **EGRB 410**: Cellular Engineering – 3
- **EGRB 411**: Cell Mechanics and Mechanobiology – 3
- **EGRB 412**: Regenerative Engineering and Medicine – 3
- **EGRB 413**: Computational and Experimental Models of Cellular Signal Transduction – 3
- **EGMN 201**: Dynamics and Kinematics – 3

| Total Hours | 3 |
The image contains a sample plan for a Biomedical Engineering Bachelor of Science (B.S.) degree at VCU. The plan includes courses for freshmen, sophomores, juniors, and seniors, with a focus on both biomedical engineering and instrumental and electronics tracks. The courses are outlined with credits and descriptions, along with semester-by-semester planning. The plan is designed to meet the prescribed requirements within a four-year course of study at VCU. It is recommended that students contact their advisor before beginning course work toward a degree.
Biomedical engineering

EGRB 303  Biotransport Processes  3
EGRB 308  Biomedical Signal Processing  4
EGRB 315  Computational Methods in Biomedical Engineering II  3
Approved social/behavioral sciences  3
Term Hours:  16

Senior year
Fall semester
EGRB 401  Biomedical Engineering Senior Design Studio  3
STAT 210  Basic Practice of Statistics  3
or  Applied Statistics for Engineers and Scientists  3
Approved natural/physical sciences  3
Technical electives  9
Term Hours:  18
Spring semester
EGRB 402  Biomedical Engineering Senior Design Studio  3
Technical electives  12
Term Hours:  15
Total Hours:  131

• Biomedical engineering (p. 7)
• Engineering (p. 7)

EGRB 101. Biomedical Engineering Practicum I. 2 Hours.
Semester course; 2 lecture hours. 2 credits. Prerequisites: registration in biomedical engineering department and permission of course coordinator. This course involves the introduction of clinical procedures and biomedical devices and technology to biomedical engineering freshmen. Students will tour medical facilities, clinics and hospitals and will participate in medical seminars, workshops and medical rounds. Students will rotate among various programs and facilities including orthopaedics, cardiology, neurology, surgery, otolaryngology, emergency medicine, pharmacy, dentistry, nursing, oncology, physical medicine, ophthalmology, pediatrics and internal medicine.

EGRB 102. Introduction to Engineering. 4 Hours.
Semester course; 3 lecture and 3 laboratory hours. 4 credits. Prerequisites: registration is restricted to biomedical engineering majors only. Introduces basic engineering principles in the context of biomedical topics, including electrical circuits and components such as resistors, capacitors, diodes, transistors, digital electronics and motors. Applications of biomedical systems including heart function, brain waves, human motion and skin responses are discussed. The laboratory introduces fundamental biomedical circuit testing and measurement and proper laboratory writing, with students required to analyze, build and test biomedical devices such as those involving ECG, EMG and Galvanic Skin Response.

EGRB 105. History of Medical Technology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Origins and recent advances in medical technologies including hearing aids, artificial knees, heart-lung machines, medical anesthesia devices and medical imaging systems such as CAT MRI.

EGRB 203. Statics and Mechanics of Materials. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 201 and PHYS 207. Restricted to biomedical engineering majors. The theory and application of engineering mechanics applied to the design and analysis of rigid and deformable structures. The study of forces and their effects, including equilibrium of two- and three-dimensional bodies, stress, strain and constitutive relations, bending, torsion, shearing, deflection, and failure of materials.

EGRB 209. Applied Physiology for Biomedical Engineers. 4 Hours.
Semester course; 3 lecture and 3 laboratory hours. 4 credits. Prerequisite: MATH 200 and MATH 201 or permission of instructor. Enrollment is restricted to biomedical engineering students. This course introduces the concepts of mathematical models and describes physiological systems using applied mathematics and engineering principles. Physiological systems will include a comprehensive study of muscle, nervous, cardiovascular, respiratory, endocrine and musculoskeletal, beginning with applied biophysical concepts in cell anatomy and physiology leading into the various physiological systems. This course also incorporates a laboratory that uses the knowledge-based tools gained through lecture and implements them in practice using exercises in biochemical and physiological calculations, osmosis, electrical network simulation of diffusion, EEG, blood pressure, ECG, spirometry and musculoskeletal anatomy.

EGRB 215. Computational Methods in Biomedical Engineering I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 201 and sophomore standing in biomedical engineering. Corequisite: MATH 301, MATH 310 or permission of instructor. The goal of this course is to enhance students’ software skills for subsequent biomedical engineering courses and laboratories, as well their careers. The course covers the basic fundamentals of programming in MATLAB, as well as data analysis of biomedical data. An important component of this course is developing problem-solving skills.

EGRB 301. Biomedical Engineering Design Practicum. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: EGRB 101, EGRB 102, EGRB 203, EGRB 215, EGRE 206 (or equivalent), each with a minimum grade of C. Restricted to students with junior standing in the biomedical engineering program. Explores the professional and ethical responsibilities of a biomedical engineer. Emphasis will be placed on design issues associated with biomedical engineering, teamwork, regulatory issues and human and animal subjects.

EGRB 303. Biomedical Engineering Practicum II. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: PHIS 309 and PHIS 310 (or equivalents); EGRB 203; MATH 301; and MATH 310. Course involves the study of fundamental principles of fluid mechanics and mass transport as well as application of these principles to physiological systems. Fluid mechanics principles covered will include conservation of mass and momentum, laminar and turbulent flow, Navier-Stokes equations, dimensional analysis, Bernoulli’s equation, and boundary layer theory. Mass transport principles will include diffusion, convection, transport in porous media and transmembrane transport. Concepts will be applied to studying diffusion in biological tissues, electrolyte transport, vascular transport, blood flow mechanics and cardiovascular flow. The course will also cover organ-specific transport processes, including oxygen transport in the lungs and blood and mass transport in the kidney.
EGRB 307. Biomedical Instrumentation. 4 Hours.
Semester course; 3 lecture and 3 laboratory hours. 4 credits.
Prerequisites: EGRB 102, EGRB 215 and EGRE 206. A study of the physical principles, design and clinical uses of biomedical instrumentation. Analysis and design of low frequency electronic circuits, which are most frequently used in biomedical instruments, will be conducted. Analysis of biosensors, biopotential electrodes, the measurements of biopotential signals including electrocardiogram, electroencephalogram and electromyogram, blood pressure, blood flow, and respiratory system will be conducted. Laboratory work on basic biomedical electronics and instrumentation will be performed.

EGRB 308. Biomedical Signal Processing. 4 Hours.
Semester course; 3 lecture and 3 laboratory hours. 4 credits.
Prerequisites: EGRB 102 and EGRB 215; MATH 301 and MATH 310; PHIS 309. Explores the basic theory and application of digital signal processing techniques related to the acquisition and processing of biomedical and physiological signals including signal modeling, AD/DA, Fourier transform, Z transform, digital filter design, continuous and discrete systems.

EGRB 310. Biomechanics. 4 Hours.
Semester course; 3 lecture and 3 laboratory hours. 4 credits.
Prerequisites: EGRB 203, EGRB 215 and PHIS 309. Corequisites: MATH 301 and MATH 310. A study of the forces, stresses and strains in the human body during normal function. Emphasis is placed on the mechanics of various components of the body including hard (bone) and soft (skin, vessels, cartilage, ligaments, tendons) tissues from a structure-function perspective. Stress and strain relationships for these biomaterials will be analyzed based upon the fundamentals of engineering mechanics. In addition, the distinctive features of biological materials will be studied with respect to their differences from nonliving materials and elaborated upon in laboratory exercises using material evaluation protocols.

EGRB 315. Computational Methods in Biomedical Engineering II. 3 Hours.
Semester course; 2 lecture and 3 laboratory hours. 3 credits. Prerequisite: EGRB 102, EGRB 215, MATH 301 and MATH 310. The goals of this course are to: (1) prepare software skills for using LabVIEW for collecting real-time data from sensors, process information and control actuators and (2) prepare mechanical design skills using SolidWorks for designing structures and mechanisms, as well as performing simple analyses for assessing mechanical design criteria.

EGRB 401. Biomedical Engineering Senior Design Studio. 3 Hours.
Semester course; 9 laboratory hours. 3 credits. Prerequisites: EGRB 101, EGRB 102, EGRB 215, EGRB 301, EGRB 303, EGRB 307, EGRB 308, EGRB 310, EGRB 315 and EGRB 427, each with a minimum grade of C. Enrollment restricted to students with senior standing in the Department of Biomedical Engineering or by permission of instructor. A minimum of nine laboratory hours per week is dedicated to the design, development and execution of the senior design (capstone) project for biomedical engineering under the direction of a faculty research adviser in biomedical engineering or an acceptable substitute as determined by the course coordinator. Tasks include team meetings (for team projects), brainstorming, sponsor advising, designing, fabrications, assembling, reviewing, studying, researching, testing and validating projects. Monthly progress reports are due to the research adviser and course coordinator. At the end of the first semester, each team will orally present to the BME faculty project background information and discuss potential technical approaches and deliverables.

EGRB 402. Biomedical Engineering Senior Design Studio. 3 Hours.
Semester course; 9 laboratory hours. 3 credits. Prerequisites: Completion of EGRB 401 with a minimum grade of C. A minimum of nine laboratory hours per week is dedicated to the design, development and execution of the senior design (capstone) project for biomedical engineering under the direction of a faculty research adviser in biomedical engineering or an acceptable substitute as determined by the course coordinator. Tasks include team meetings (for team projects), brainstorming, sponsor advising, designing, fabrications, assembling, reviewing, studying, researching, testing and validating projects. Monthly progress reports are due to the research adviser and course coordinator. Final project reports must be submitted before the end of the semester. All design teams must participate in the School of Engineering public poster session. At the end of the semester and conclusion of the two-semester design process, teams must present their final designs and deliverables before the BME faculty.

EGRB 403. Tissue Engineering. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: PHIS 309 or permission of instructor. Enrollment restricted to students with junior standing in engineering. Study of the design, development and clinical application of tissue engineered components for use in the human body. Analysis of biology, chemistry, material science, engineering, immunology and transplantation as pertains to various tissue engineered components including blood vessels, bone, cartilage, pancreas, liver and skin.

EGRB 405. Finite Element Analysis in Solid Mechanics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: EGRB 310 and MATH 301. Finite element analysis as presented in this course is a numerical procedure for solving continuum mechanics problems that cannot be described by closed-form mathematical solutions. Emphasis will be placed on understanding the theoretical basis for the method, using a commercial software program, and understanding the volume of information that can be generated. Applications to both one- and two-dimensional problems in solid mechanics and biomechanics will be explored.

EGRB 406. Artificial Organs. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: PHIS 309, EGRB 303, EGRB 307 and EGRB 310, or permission of instructor. This course explores the design, operating principles and practices regarding artificial organs and their use in the human body. Analysis of dialysis systems for kidney replacement, artificial hearts and heart assist devices, cardiac pacemakers, sensory organ assist and replacement devices, and artificial liver and pancreas devices. Design aspects, legal ramifications, regulatory issues and clinical implantation issues will be addressed.

EGRB 407. Physical Principles of Medical Imaging. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: junior standing in the School of Engineering and PHYS 208. A study of the physical principles and basic clinical uses of medical imaging. Analysis of radiation and interaction of radiation, generation and control of X-rays, X-ray diagnostic methods, X-ray computed tomography (CT), magnetic resonance imaging (MRI) and ultrasonic imaging will be conducted. Basic principle of radionuclide imaging also will be introduced.
EGRB 408. Advanced Biomedical Signal Processing. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: EGRB 308.
This course will briefly review the basic theory of discrete-time signal
processing techniques in biomedical data processing. Advanced signal
processing techniques including adaptive signal processing, wavelets,
spectral estimation and multirate signal processing will be employed.
Specific examples utilizing electrocardiogram (ECG) and other biological
signals are provided. Topics covered are alternate phenomenon in
biological systems, late potential in ECG, intrapotential in ECG and
cohere analysis.

EGRB 409. Microcomputer Applications in Biomedical Engineering. 3
Hours.
Semester course; 2 lecture and 3 laboratory hours. 3 credits. Prerequisite:
EGRB 307. Covers microcomputer applications (hardware and software)
as applied to biomedical science and biomedical engineering. Basic
hardware components of a microcomputer are discussed with particular
reference to configurations needed for analyzing biomedical events.
Software applications including data encoding, data storage, graphical
interfaces and real-time processing are explored for analysis of
physiological and biomedical signals. Students will develop algorithms
using LabView and MatLab to solve problems in biomedical engineering
in the laboratories.

EGRB 410. Cellular Engineering. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: PHIS 309
and PHIS 310, both with minimum grades of C. This course will be
a detailed study of the structure and function of the cell from an
engineering perspective. Fundamental molecular biology, cell biology
and biochemistry topics (cellular structure, signal transduction, cell
adhensions, cytoskeleton) will be introduced. Engineering principles
(kinetics, transport, mechanics, thermodynamics, electrochemical
gradient) will be applied to these topics. Emphasis is placed on methods
to disrupt, enhance or mimic in vivo cellular function in biomedical
applications.

EGRB 411. Cell Mechanics and Mechanobiology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: EGRB 310
and EGRB 410 with minimum grades of C or permission of instructor.
Focusing on cellular-extracellular matrix interactions, students will gain
a quantitative understanding of the way cells detect, modify and respond
to the physical properties within the cell environment. Coverage includes
the mechanics of single-molecule polymers, polymer networks, two-
dimensional membranes, whole-cell mechanics and mechanobiology.
Mechanobiology topics include cancer and development, pulmonary
system, cardiovascular system, and the nervous system. Students
will gain understanding of techniques in cellular manipulation and
quantification of cellular forces.

EGRB 412. Regenerative Engineering and Medicine. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: PHIS 309 or
equivalent with minimum grade of C. Students will apply fundamental
concepts of cell and molecular biology, biochemistry, medicine and
pathology, as well as material science and engineering principles to
design novel strategies for cell and drug delivery, tissue engineering and
regenerative medicine. Emphasis will be placed on designs and methods
to solve current complex biomedical problems.

EGRB 413. Computational and Experimental Models of Cellular Signal
Transduction. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: EGRB 215
and EGRB 410 with minimum grades of C. Students will study the
process by which an extracellular protein binding event is transduced
and interpreted as an incoming signal into a cell. Students will learn
the biology of cellular signal transduction and will also learn how to
apply computational models and experimental techniques to predict
and investigate these pathways. Students will follow the course of a
protein within a signal transduction cascade, from binding to a receptor,
activating intracellular pathways, inducing new transcription and
translation and targeting of the protein to its final location. Students
will develop MATLAB-based mathematical models to predict signal
transduction dynamics, and then will study experimental techniques that
are used to both disrupt and measure signal transduction.

EGRB 420. Assistive Technology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: EGRE 206
or equivalent; EGRB 310; and PHIS 309 and PHIS 310 or equivalents;
or permission of instructor. Enrollment is restricted to biomedical
engineering students or with permission of instructor. This course
explores the principles and practice regarding the development of
assistive technology for individuals with disabilities. The course will
address the human user considerations that need to be taken into
account in developing technology for individuals with different disabilities
or multiple disabilities. It will also provide a general overview of current
technology and software algorithms used. The four main areas of
assistive technology that will be considered are for the deaf and hard of
hearing, individuals who are blind and visually impaired, individuals with
cognitive impairments, and individuals with motor impairments.

EGRB 421. Human Factors Engineering. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: PHIS 309
and PHIS 310 (or equivalents), and EGRB 310. This course explores
the principles and practices regarding ergonomics and human factors
engineering and the interaction of biomedical engineering with human
function. Analysis of the functions of the human body regarding motion,
sensory mechanisms, cognition and interaction with the environment
will be included. Interactions of the human body with technology, workplaces,
equipment and computers will be examined. Design of workplaces for
optimal human performance will be discussed. Analysis of the design and
arrangement of controls and displays will be covered.

EGRB 422. Human Performance Measurement Engineering. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: EGRB 307,
EGRB 308, EGRB 421 and PHIS 309 or equivalent, each completed
with a minimum grade of C, or by permission of instructor. Enrollment
is restricted to biomedical engineering majors or with permission
of instructor. Course explores the principles and practices of
human performance measurement including direct and indirect
measurement techniques and analysis. Course addresses the subjective,
psychophysical and physiological methods related to the measurement,
analysis and quantification of human performance.
EGRB 423. Rehabilitation Engineering and Prostheses. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: EGRB 203, PHIS 309 and PHIS 310, or permission of instructor. Enrollment restricted to biomedical engineering majors or with permission of instructor. This course explores the principles and practices regarding the development of rehabilitation therapy devices and prosthetics. The course will further address the human user and factors that must be considered when developing devices and engineering solutions for individuals with different therapy and prosthetic needs. The course will also provide a general overview of current technologies and the engineering principles behind these designs.

EGRB 427. Biomaterials. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: junior standing in biomedical engineering, PHIS 309 and 310, or permission of instructor. Principles of materials science as it relates to the use of materials in the body. Characterization of biomaterials. Study of the properties of biomedical materials used as implants, prostheses, orthosis and as medical devices in contact with the human body. Analysis of physical, chemical, thermal and physiological response factors associated with materials and implant devices used in the human body.

EGRB 491. Special Topics. 1-4 Hours.
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated with different topics. Advanced study of a selected topic in biomedical engineering. See the Schedule of Classes for specific topics to be offered each semester and prerequisites, corequisites or restrictions.

Engineering
ENGR 100. Engineering Student Success. 0 Hours.
Semester course; seminar hours. 0 credits. Enrollment is restricted to new first-year students in the School of Engineering; required for students admitted conditionally. Students will meet for a 90-minute class once per week for five weeks. The course is dedicated to helping students understand the expectations and responsibilities of being a college student. Presentations will center on planning the semester, academic professionalism, study skills and test-taking strategies, financial literacy, health and wellness, time management, and the Honor Code. Seminars will be supplemented throughout the semester with online assignments to reinforce the discussions. Graded as pass/fail.

ENGR 101. Introduction to Engineering. 4 Hours.
Semester course; 3 lecture and 3 laboratory hours. 4 credits. Prerequisites: admission to the School of Engineering or permission of instructor. Introduces basic circuits including resistors, diodes, transistors, digital gates and motors. Simple electromechanical systems are considered including motors, gears and wheels. The laboratory introduces fundamental circuit testing and measurement, and proper laboratory notebook writing; students are required to analyze, build and test a digitally controlled robot.

ENGR 111. Innovation Shop Training I. 0.5 Hours.
Semester course; 1 laboratory hour. 0.5 credits. Enrollment restricted to students in the School of Engineering. The course provides training on innovation shop safety, includes a tour of the shop, measuring and layout tools and techniques, use of general manual and powered hand tools. Students will be instructed on the use of a bench-top drill press, deburring and finishing tools, 3D printing, laser engraving and thermoforming equipment. Students need to achieve a minimum score of 76% in the class to attain Level I (Blue) certification. Only certified students have permission to use tools and equipment covered in this training. Graded as Pass/Fail.

ENGR 211. Innovation Shop Training II. 1 Hour.
Semester course; 2 laboratory hours. 1 credit. Prerequisite: ENGR 111. Enrollment restricted to students in the School of Engineering. The course provides training on machine/innovation shop safety, blueprint reading, measuring and layout tools and techniques, and use of general and powered hand tools. Students will be instructed on sawing, sanding, drilling and tapping operations, 3D printing and laser engraving/cutting equipment. Hands-on graded assignment is the part of the course.

ENGR 291. Special Topics in Engineering. 1-5 Hours.
Semester course; variable hours. 1-5 credits. Prerequisite: to be determined by the instructor. Specialized topics in engineering designed to provide a topic not covered by an existing course or program. General engineering or multidisciplinary. May be repeated with different content. Graded as pass/fail or normal letter grading at the option of the instructor. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

ENGR 296. Part-time Internship Experience. 0 Hours.
Semester course; 0 credit. Students may attempt this course a total of six times. Enrollment restricted to School of Engineering majors. The student works part time in an approved internship and must work a minimum of 90 hours, but less than 300 hours during the semester. The student works to meet learning objectives while gaining practical experience relevant to their major. The student completes assignments to document, assess and reflect on their learning experience. The supervisor and student both complete evaluations of the learning experience. Graded pass/fail.

ENGR 303. Junior Seminar. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: permission of instructor. This course provides students an opportunity to explore business and leadership topics. Topics include the fundamentals of product design and new product development, manufacturing and quality systems, finances and financial reports, ethics in the workplace, intellectual property, teamwork, leadership and communications. Students will be assigned selected readings, written compositions and oral presentations. This course prepares the student to participate in the Engineering Laboratory/Manufacturing Internship.

ENGR 311. Innovation Shop Training III. 1 Hour.
Semester course; 2 laboratory hours. 1 credit. Prerequisite: ENGR 211. Enrollment is restricted to students with Level II (Red) certification. The Level III (Green) course provides basic training on set-up and operation of manual milling machines and the lathe. The course covers covering tool, speed and feed calculation. Students must develop a technological process and machine metal parts per assigned drawings on vertical mill and lathe. They will also use other techniques and equipment that were covered in previous levels. Students need to achieve a minimum score of 76 % in the class to attain Level III (Green) certification. Only certified students have permission to use tools and equipment covered in this training.
ENGR 395. Professional Development. 1 Hour.
Semester course; 1 lecture and 1 workshop hour. 1 credit. Enrollment is restricted to majors in the School of Engineering. Professional development course to help prepare students to find a job and succeed in a professional environment, and specifically work as an intern or in a cooperative education position. Topics covered include career paths; job searches; resume and cover letter writing; preparing for the interview; personal assessment of interests, values and strengths; networking; professional and ethical behavior on the job; overview of legal issues related to hiring, such as non-disclosure agreements and non-compete clauses; overview of personal finance management at the first job; workplace safety; and expectations and requirements for internships and cooperative education positions.

ENGR 396. Internship Experience. 0 Hours.
Semester course; 0 credit. Students may attempt this course a total of three times. Enrollment restricted to School of Engineering majors. The student works in an approved internship and must work a minimum of 300 hours during the semester. The student works to meet learning objectives while gaining practical experience relevant to their major. The student completes assignments to document, assess and reflect on their learning experience. The supervisor and student both conduct evaluations of the learning experience. Graded pass/fail.

ENGR 398. Cooperative Education Experience. 0 Hours.
Semester course; 0 credits. Students may attempt this course a total of four times. Prerequisite: ENGR 395. Restricted to School of Engineering majors in good academic standing. The student works full-time in an approved cooperative education position. The student works to meet specific learning objectives while gaining practical experience relevant to their major. The student completes assignments to document, assess and reflect on their learning experience. The supervisor/mentor and student both conduct midterm and final evaluations of the learning experience. Graded pass/fail.

ENGR 399. Cooperative Education Experience II. 3 Hours.
Semester course; 3 credits. Prerequisite: ENGR 398. Restricted to School of Engineering majors in good academic standing. A student that has completed at least one work term in a full-time approved cooperative education position completes an additional full-time work term. The student works to meet specific learning objectives while gaining practical experience relevant to their major. The student completes assignments to document, assess and reflect on their learning experience. The supervisor/mentor and student both conduct midterm and final evaluations of the learning experience.

ENGR 402. Senior Design Studio (Seminar). 1 Hour.
Continuous courses; 1 lecture hour. 1-1 credit. Prerequisites: senior standing and participation in a senior design (capstone) project; completion of ENGR 402 to enroll in ENGR 403. This weekly seminar presents and discusses topics relevant to senior-level engineering students in support of the capstone project and upcoming graduation. A single course coordinator manages and administers the course and schedules the various faculty lectures and guest speakers. Topics include, but are not limited to, the following: proposal writing, project planning and management, scheduling resources and budgeting for technical projects, patents and intellectual property, quality systems (six sigma, ISO standards, statistical process control), entrepreneurship, creativity and innovation and professional registration.

ENGR 403. Senior Design Studio (Seminar). 1 Hour.
Continuous courses; 1 lecture hour. 1-1 credit. Prerequisites: senior standing and participation in a senior design (capstone) project; completion of ENGR 402 to enroll in ENGR 403. This weekly seminar presents and discusses topics relevant to senior-level engineering students in support of the capstone project and upcoming graduation. A single course coordinator manages and administers the course and schedules the various faculty lectures and guest speakers. Topics include, but are not limited to, the following: proposal writing, project planning and management, scheduling resources and budgeting for technical projects, patents and intellectual property, quality systems (six sigma, ISO standards, statistical process control), entrepreneurship, creativity and innovation and professional registration.
ENGR 496. Internship Review. 0 Hours.
Semester course; 0 credits. Prerequisite: ENGR 296 or ENGR 396. Restricted to School of Engineering majors. This course is to be taken following the completion of a minimum of 300 hours of approved internship experience relevant to the student’s major and documents that a student has fulfilled all internship requirements, including a final evaluation by the employer, a final self-evaluation, a final report describing the experience and a final oral presentation about the experience. Graded pass/fail.

ENGR 497. Vertically Integrated Projects. 1,2 Hour.
Semester course; 3 or 6 laboratory hours. 1 or 2 credits. May be repeated for a maximum total of 8 credits Prerequisites: permission of the project faculty adviser. This course provides undergraduate students the opportunity to participate in multiyear, multidisciplinary projects under the guidance of faculty and graduate students in their areas of expertise. As they address research and development issues, students learn and practice many different professional skills, make substantial technical contributions to the project, and experience many different roles on a large, multidisciplinary design/discovery team. Students must earn a minimum of 4 credits in ENGR 497 with a minimum grade of C in order for these credits to be eligible to count toward a technical or departmental elective. More restrictive requirements may be imposed by individual departments.

ENGR 498. Review of Cooperative Education Experience. 0 Hours.
Semester course; 0 credits. Prerequisite: ENGR 398. Restricted to School of Engineering majors. This course is completed following the final work term of a cooperative education experience and is required to obtain transcript notation to document that a student has fulfilled all the requirements of the school's cooperative education program. The requirements include a final evaluation by the employer, a final self-evaluation, a final report describing the experience and a final oral presentation about the experience.