Course Recommendations

Freshman/Sophomore	Junior	Senior
Mathematics (6 courses) MA 1021 (Calculus I) MA 1024 (Calculus IV) MA 1022 (Calculus II) MA 2051 (Differential Equations) MA 1023 (Calculus III) MA 2611 (Statistics) **Biology (2 courses)** BB 2550 (Cell Biology) BB 3110 (Animal Physiology) **Chemistry (2 courses)** CH 1010 (Chemistry I) CH 1020 (Chemistry II) **Physics (2 courses)** PH 1110 (Physics I) PH 1120 (Physics II) **Supplemental Science (2 courses)** Pick 2 from BB, CH, or PH (See suggested courses from specialization areas listed below) **BioMed. Eng. (select 3 courses)** BE 1001 (Intro. to Bio. Med. Eng.) BE 2204 (Bioelectric Foundations) BE 2504 (Foundations in Biomechanics) BE 2604 (Foundations in Biol. Transport) **H&A Sufficiency (2 Units)** **Social Science** **Physical Education**	**IQP** **BioMed. Eng. (2 courses)** BE 3300 (BME Design) BE 3110 (Exp. Physiol.)	**MQP**
	Social Science **Free Electives** **Physical Education** **From the biomedical engineering specialization areas listed below, select nine (9) courses from BME or other engineering disciplines (four of these courses must be at the 3000-level or above, and must include two BME courses at the 4000-level or above).**	
Note: The total minimum number of BME courses, not including BE 3110, is eight (8)		

Degree Requirements

H&A Sufficiency (2 Units)		
	IQP (1 Unit)	
Math / Science (4 Units)		
Supplemental Science (2/3 Unit)		
		MQP (1 Unit)
Biomedical and other Engineering Topics (13/3 Units)		
	BE 3110 Living Systems Lab (1/3 Unit)	
Social Science (2/3 Units)		
	Free Electives (2/3 Unit)	
Physical Education (1/3 Units)		

Biomedical Engineering Specialization Areas

The field of Biomedical Engineering (BME) has a number of subdivisions, or specializations, that are briefly described below. Preferred course listings are given in order to help students plan their program of study in consultation with their academic advisor.

Biomaterials

Students combine biology and physiology coursework with interests in materials science and engineering to understand the development, processing and performance testing of biomaterials used in medical devices. Typical MQP topics include: development of collagen-based biomaterials for orthopedic and applications and tissue engineering, evaluation of surgical adhesives, shape memory polymers in staples, fracture fixation devices and stents, investigation of the effects of sterilization on UHMWPE and growth of hydroxyapatite on collagen.

Supplemental Science (Select two courses)
Preferred choices include:
BB 2940 – Experimental Biology
CH 2310 – Organic Chemistry I
CH 4110 – Biochemistry I
CH 4550 – Polymer Chemistry
Engineering (Select nine courses)
Select three fundamental engineering courses; preferred choices include:
ES 2001 – Introduction to Materials Science
ES 2501 – Introduction to Static Systems
ES 2502 – Stress Analysis
ES 2503 – Introduction to Dynamic Systems
Select three 3000-level (or higher) engineering courses; preferred choices include:
ES 3001 – Introduction to Thermodynamics
ME 3501 – Continuum Mechanics
ME 3502 – Advanced Mechanics of Materials
ME 4821 – Chemistry, Properties and Processing of Plastics
Select three 3000- and/or 4000-level BME courses; preferred choices include [Note #2]:
BE/ME 4504 – Biomechanics
BE/ME 4814 – Biological Materials
BE 4828 – Biomaterials-Tissue Interactions
BE/ME 550 – Tissue Engineering

Note #2: At least two of the BME courses must be at the 4000-level or above. Graduate-level courses can substitute for 4000-level courses.

Biomechanics

Students apply biology and physiology coursework with continuum mechanics, biomechanics and thermofluids to understand the mechanical properties of tissues such as bones and blood vessels in both healthy and diseased states. Interactions between tissues and medical devices (e.g. orthopedic, dental) are also characterized. Typical MQP topics include: soft tissue mechanics, flow in blood vessels, joint kinematics, medical device design, sports biomechanics and rehabilitation.

Supplemental Science (Select two courses)
Preferred choices include:
BB 2940 – Experimental Biology
CH 2310 – Organic Chemistry I
CH 4110 – Biochemistry I
CH 4550 – Polymer Chemistry
Engineering (Select nine courses)
Select three fundamental engineering courses; preferred choices include:
ES 2001 – Introduction to Materials Science
ES 2501 – Introduction to Static Systems
ES 2502 – Stress Analysis
ES 2503 – Introduction to Dynamic Systems
Select three 3000-level (or higher) engineering courses; preferred choices include:
ES 3001 – Introduction to Thermodynamics
ES 3004 – Fluid Mechanics
ME 3310 – Dynamics of Mechanisms and Machines
ME 3501 – Continuum Mechanics
ME 3502 – Advanced Mechanics of Materials
ME 3506 – Rehabilitation Engineering
Select three 3000- and/or 4000-level BME courses; preferred choices include [Note #2]:
BE/ME 4504 – Biomechanics
BE/ME 4606 – Biofluids
BE/ME 4814 – Biological Materials

Note #2: At least two of the BME courses must be at the 4000-level or above. Graduate-level courses can substitute for 4000-level courses.

Biomedical Imaging

Courses are available to support the development of a student's interest in biomedical imaging, including image acquisition and processing. Students blend the disciplines of physics, chemistry, mathematics, biology, computer science, and engineering according to their individual interests. Typical MQP activities include: imaging instrumentation development, image processing and analysis, diagnosis and testing. Departmental imaging facilities and computer and software support are available.

Supplemental Science (Select two courses)
Preferred choices include:
CH 1030 – Chemistry III (Equilibrium)
CH 4110 – Biochemistry
PH 1130 – Introduction to 20th Century Physics
PH 1140 – Oscillations and Waves
PH 2501 – Photonics
PH 2601 – Photonics Laboratory
Engineering (Select nine courses)
Select three fundamental engineering courses; preferred choices include:
EE 2011 – Introduction to Electrical and Computer Engineering
EE 2111 – Physical Principles of ECE Applications
EE 2112 – Electromagnetic Fields
EE 2311 – Continuous-Time Signal and System Analysis
ES 2011 – Introduction to Nuclear Technology
Select three 3000-level (or higher) engineering courses; preferred choices include:
EE 3113 – Introduction to RF Circuit Design
EE 3204 – Microelectronic Circuits II
ME 4922 – Theory and Practice of Laser Instrumentation
NE 4301 – Radiation Transport
Select three 3000- and/or 4000-level BME courses; preferred choices include [Note #2]:
BE 3011 – Bioinstrumentation and Biosensors
BE 4011 – Biomedical Signal Analysis
BE 4201 – Biomedical Imaging
BE 581 – Medical Imaging Systems
BE 582 – Principles of In Vivo Nuclear Magnetic Resonance Imaging

Note #2: At least two of the BME courses must be at the 4000-level or above. Graduate-level courses can substitute for 4000-level courses.

Biomedical Sensors and Instrumentation

Students select courses to develop their ability concerning the principles, applications, and design of biomedical sensors and instrumentation systems. Students should select courses, which deal with basic science, the principles of electrical engineering, biology and physiology, signal analysis, and engineering design. Typical MQP projects include: biopotential instrumentation systems, optical sensors, noninvasive blood analyte measurements, and biological measurement systems.

Supplemental Science (Select two courses)
Preferred courses include:
BB 2940 – Experimental Biology
PH 1130 – Introduction to 20 th Century Physics
PH 1140 – Oscillations & Waves
PH 2501 – Photonics
Engineering (Select nine courses)
Select three fundamental ECE courses; preferred choices include:
EE 2011 – Introduction to Electrical and Computer Engineering
EE 2022 – Introduction to Digital Circuits & Computer Engineering
EE 2111 – Physical Principles of ECE Application
EE 2201 – Microelectronic Circuits I
EE 2311 – Continuous-Time Signal & System Analysis
EE 2312 – Discrete-Time Signal & System Analysis
EE 2799 – Electrical & Computer Engineering Design
Select two 3000-level (or higher) engineering courses; preferred choices include:
ES 3011 – Control Engineering
EE 3204 – Microelectronic Circuits II
EE 3804 – Advanced Logic Design
Select four 3000- and/or 4000-level BME courses; preferred choices include [Note #2]:
BE 3011 – Bioinstrumentation and Biosensors (Bioinstrumentation I)
BE 4011 – Biomedical Signal Analysis
BE 4023 – Biomedical Instrumentation I

Note #2: At least two of the BME courses must be at the 4000-level or above. Graduate-level courses can substitute for 4000-level courses.

Tissue Engineering

Students combine cell biology and physiology coursework with interests in biomaterials, biomechanics or biotransport phenomena to understand the structural, mechanical and biological processes associated with designing and developing living systems to repair or replace damaged tissues or organs. Typical MQP topics include: designing and testing polymer scaffolds, measuring cellular function on scaffolds and designing bioreactors to grow constructs to repair tissues such as tendon, ligament, cartilage, skin and bone.

Supplemental Science (Select two courses)
Preferred choices include:
BB 2940 – Experimental Biology
CH 2310 – Organic Chemistry I
CH 4110 – Biochemistry I
CH 4550 – Polymer Chemistry
Engineering (Select nine courses)
Select three fundamental engineering courses; preferred choices include:
ES 2001 – Introduction to Materials Science
ES 2501 – Introduction to Static Systems
ES 2502 – Stress Analysis
ES 2503 – Introduction to Dynamic Systems
Select three 3000-level (or higher) engineering courses; preferred choices include:
ES 3002 – Mass Transfer
ES 3003 – Heat Transfer
ES 3004 – Fluid Mechanics
ME 3502 – Advanced Mechanics of Materials
ME 4821 – Chemistry, Properties and Processing of Plastics
Select three 3000- and/or 4000-level BME courses; preferred choices include [Note #2]:
BE/ME 4606 – Biofluids
BE/ME 4814 – Biological Materials
BE 4828 – Biomaterials-Tissue Interactions
BE/ME 550 – Tissue Engineering

Note #2: At least two of the BME courses must be at the 4000-level or above. Graduate-level courses can substitute for 4000-level courses.

Preparation for Medical, Dental, or Veterinary Schools

Students who wish to prepare for medical, dental, or veterinary school can choose any of the BME specialization areas listed above. These students should select courses that deal with basic science and the principles of engineering; however, special requirements for medical school must be met within the confines of those specialization areas. These include:

Supplemental science courses:
Since a full year of general chemistry and physics is required, students must take one additional course in both chemistry and physics (preferably CH 1030 and PH 1140) in addition to the two in each area (CH 1010, CH 1020, PH 1110, and PH 1120) required by the BE program.

Free Electives:
Because of the requirement of three organic chemistry courses (with labs), it is recommended that students use their two free electives for two (CH 2310 and CH 2320) of the three courses. The third course (CH 2360) would be taken outside of the BE program requirements.

Students should also consult the Pre-Health Center, in addition to their BME advisor, for current information about course requirements for admission into medical or veterinary school.

NEW BIOMEDICAL ENGINEERING COURSES

BE 2204 – Bioelectric Foundations

Cat. I

An introduction to the origins and characteristics of the electric and electromagnetic signals that arise in biological tissues. Topics include the behavior of excitable cells and tissues, the intrinsic electrical and magnetic properties of biological tissues, and the response of excitable cells to electric and magnetic field stimulation. Laboratory projects include the measurement of bioelectric signals (EMG, EKG, EEG, EOG, and evoked response) and the fundamentals of data acquisition, analysis, and statistics. The principles of writing and maintaining a laboratory notebook are also developed and used.

Recommended background: BB 2550 or equivalent, PH 1120 or PH 1121.
Students who have received credit for BE 4101 may not receive credit for BE 2204.
(This course replaces BE 4101, which will no longer be taught)

BE 2504 – Foundations in Biomechanics

Cat. I

This course is an introduction to the analysis of the musculoskeletal systems using principles of engineering mechanics. Basic principles of mechanics, stress, strain and deformation in beams are presented and used to characterize the material properties of tissues such as skin, tendon, ligament, bone and cartilage. Principles of biomechanics are also applied to the design of medical devices and bioengineered tissues. Topics include forces, moments of forces, free body diagrams, principal stresses, transverse shear stresses and beam loading.

Recommended background: BB 2550 or equivalent, MA 2501, PH 1120 or PH 1121.
Students who have previously received credit for BE 4504 may not receive credit for BE 2504.

BE 2604 – Foundations in Biological Transport Phenomena

Cat. I

This course is an introduction to the analysis of complex biological systems using principles of transport phenomena. Basic theories of momentum transport, mass transport and energy transport are presented and applied to cellular and mammalian physiology. Principles of transport phenomena are also applied to the design of medical devices and bioengineered tissues. Topics include differential and integral balances, rheology of Newtonian and non-Newtonian fluids, diffusion in reacting systems and homogeneous vs. heterogeneous reaction systems.

Recommended background: BB 2550 or equivalent, MA 2501, PH 1120 or PH 1121.
Students who have received credit for BE 3101 may not receive credit for BE 2604.
(This course replaces BE 3101, which will no longer be taught)

BE4023 – Biomedical Instrumentation Design I

Cat II

This course builds on the fundamental knowledge of bioinstrumentation and biosensors presented in BE3011. Lectures and hands-on laboratory experiments cover the principles of designing, building and testing analog instruments to measure biological events. Design laboratories will include biopotential amplifiers and biosensor/bioinstrumentation systems for the measurement of physiological parameters.

Recommended background: BE 2204 and BE 3011

BE 4828 – Biomaterials-Tissue Interactions

Cat. I

This course examines the principles of materials science and cell biology underlying the design of medical devices, artificial organs and scaffolds for tissue engineering. Molecular and cellular interactions with biomaterials are analyzed in terms of cellular processes such as matrix synthesis, degradation and contraction. Principles of wound healing and tissue remodeling are used to study biological responses to implanted materials and devices. Case studies will be analyzed to compare tissue responses to intact, bioresorbable and bioerodible biomaterials. Additionally, this course will examine criteria for restoring physiological function of tissue and organs and investigate strategies to design implants and prostheses based on control of biomaterial-tissue interactions.

Recommended background: BE 2604, BB 2550 or equivalent, ES 2001 or equivalent, PH 1120 or PH 1121.

CHANGES TO EXISTING BME COURSE

BE 3110 – Experimental Physiology for Engineers (change in recommended background)

Recommended background: BE 2204 and BB 2550 or equivalent.