Biomedical Engineering

Ranu Jung, *Chair and Professor*
Michael Brown, *Senior Instructor*
Michael Christie, *Instructor and Undergraduate Advisor*
Anuradha Godavarty, *Associate Professor*
Yen-Chih Huang, *Assistant Professor*
Shuliang Jiao, *Associate Professor*
Chenzhong Li, *Associate Professor*
Wei-Chiang Lin, *Associate Professor and Graduate Program Director*
Anthony McGoron, *Associate Professor and Undergraduate Program Director*
Sharan Ramaswamy, *Assistant Professor*
Jessica Ramella-Roman, *Associate Professor*
Jorge Riera Diaz, *Associate Professor*
Nikolaos Tsoukias, *Associate Professor*

The mission of the Department of Biomedical Engineering is to integrate academia, clinical medicine, and the biomedical industry:

- In the education and training of the next generation of biomedical engineers;
- In research and development activities leading to innovations in medical technology;
- In transfer of that medical technology to commercialization and clinical implementation; and
- In the continuing development of biomedical engineering as a profession, its impact on the delivery of health care, and its role in the sustainability and growth of the local and national economies.

The Department of Biomedical Engineering at Florida International University offers a curriculum designed to give the student a thorough understanding of the basic laws of science and simultaneously to stimulate and develop creative and innovative thinking, a professional attitude, economic judgment, and environmental consciousness. The aim is to develop the student's potential to the fullest, to prepare the student for superior performance as a biomedical engineer, and to provide the student with the fundamental principles necessary for pursuing advanced study in the diverse fields of engineering, science, and business.

The undergraduate Biomedical Engineering Program at FIU provides an education that is at the interface of engineering and biology, with an emphasis on engineering living systems down to the cellular and molecular levels, and adequately prepares graduates for a wide range of career opportunities.

The objectives of the undergraduate Biomedical Engineering Program at FIU are the following:

1. To produce graduates that continue in one or both of the following:
   a. Advanced study in engineering, medicine, or applied sciences
   b. Professional practice as an engineer in a biomedical or health care related field
2. To produce graduates whose careers demonstrate proficiency in one or more of the following:
   a. Clinical application of biomedical engineering tools
   b. Product development, manufacturing, and commercialization in the biomedical industry
   c. Participation in diverse teams
   d. Biomedical engineering research
3. To produce graduates who have effective communication skills and a commitment to professionalism, leadership, ethics, and community service.

Bachelor of Science in Biomedical Engineering

Degree Program Hours: 128

Common Prerequisite Courses and Equivalencies

FIU Course(s)	Equivalent Course(s)
MAC 2311	MACX311[1]
MAC 2312	MACX312[1]
MAC 2313	MACX313[1]
MAP 2302	MAPX302
PHY 2048	PHYX048
PHY 2048L	PHYX048L
PHY 2049	PHYX049
PHY 2049L	PHYX049L
CHM 1045	CHMX045[2]
CHM 1045L	CHMX045L[2]
CHM 1046	CHMX046
CHM 1046L	CHMX046L
BSC 1010	BSCX010
BSC 1010L	BSCX010L
CHM 2210	CHMX210
CHM 2210L	CHMX210L

[1]***OR*** *MACX281, MACX282, MACX283*
[2]***OR*** *CHSX440 Chemistry for Engineers*

Courses which form part of the statewide articulation between the State University System and the Florida College System will fulfill the Lower Division Common Prerequisites.

For generic course substitutions/equivalencies for Common Program Prerequisites offered at community colleges, state colleges, or state universities, visit: **http://www.flvc.org**, See Common Prerequisite Manual.

Common Prerequisites

MAC 2311	Calculus I
MAC 2312	Calculus II
MAC 2313	Multivariable Calculus
MAP 2302	Differential Equations
PHY 2048	Physics I w/ Calc
PHY 2048L	General Physics I Lab
PHY 2049	Physics II w/ Calc
PHY 2049L	General Physics II Lab
CHM 1045	General Chemistry I
CHM 1045L	Gen Chem I Lab
CHM 1046	General Chemistry II
CHM 1046L	Gen Chem II Lab
BSC 1010	General Biology I
BSC 1010L	Gen Biology I Lab
CHM 2210	Organic Chemistry I
CHM 2210L	Organic Chemistry I Lab

Admission to Undergraduate Program in Biomedical Engineering

Applicants to the Biomedical Engineering program must submit an Application for Admission to the University and follow regular University admission procedures. Applicants must meet the University's requirements for admission

before being eligible for admission to the Biomedical Engineering program. Continuing FIU students who seek admission to the BME program must submit a completed Academic Program/Plan Declaration or Change Form to the department of Biomedical Engineering.

To be eligible for acceptance into the Biomedical Engineering program, students must have:

1. Satisfied general University requirements for admission.
2. First time in college or have completed the Associate in Arts degree or its equivalent;
3. Continuing FIU students and transfer students must complete all pre-core courses (listed below) and achieved a minimum of "C" and an average grade point average of at least 2.5 in all Common Prerequisite courses taken;
4. Achieved a cumulative grade point average of 2.5;
5. If applicant is an international student whose native language is not English, have achieved a minimum score of 500 on the paper-based TOEFL, 173 on the computer-based TOEFL. [International applicants should study the "General Admission" requirements for foreign students in the "Admissions" section of this catalog].

Pre-Core Courses (17 Credits)

BSC 1010	General Biology I
BSC 1010L	General Biology I Lab
CHM 1045	General Chemistry I
CHM 1045L	General Chemistry I Lab
PHY 2048	Physics I with Calculus
PHY 2048L	General Physics I Lab
MAC 2311	Calculus I

Lower Division Preparation

Lower division requirements include at least 60 hours of pre-engineering credits (see the Undergraduate Studies portion of this catalog for specific requirements). These courses include the common courses listed above. A minimum grade of "C" is required in all writing courses, as well as in all of the common prerequisite courses. In addition, a minimum GPA of 2.5 is required for the common prerequisite courses.

All students must meet the University Foreign Language Requirement and all of the state and university requirements for graduation.

Biomedical Engineering Curriculum

The BS curriculum weaves a strong life science foundation with multidisciplinary engineering fundamentals.

Biomedical Engineering Courses

BME 1008	Intro to Biomedical Engineering	2
BME 1054L	Introduction to Biomedical Engineering Computing	1
STA 3033	Intro Probability Statistics	3
EIN 3235	Evaluation of Engineering Data	3
BME 2740*	BME Modeling and Simulation	3
BME 3721*	BME Data Evaluation Principles	3
BME 3403	Eng Analysis Biological Systems I	3
BME 3404	Eng Analysis Biological Systems II	3
EEL 3110	Circuit Analysis	3
EEL 3110L	Circuits Lab	1
EGM 3503	Applied Mechanics	4
BME 3632	BME Transport	3
BME 4011	Clinical Rotations	1
BME 4050L	BME Lab I	1
BME 4051L	BME Lab II	1
BME 4100	Biomaterials Science	3
EEE 4202C	Med Instrument Design	4
BME 4800	Design Biomedical Systems and Devices	3
BME 4090	Design Project Organization	1
BME 4908	Senior Design Project	3
BME 4930	Undergraduate Seminar	0
Electives (9 credits minimum Engineering Electives**)		18

*These courses have four contact hours of which one hour is a non-credit tutorial/lab session.
**Nine out of the required eighteen elective credits can be either from Engineering or Science. All electives and equivalencies for courses transferred from other institutions must be approved by the Undergraduate Advisor.

Students must maintain a cumulative GPA of at least 2.0 in all Engineering courses.

Biomedical Engineering Program Requirements - Freshman to Senior

First Semester: (18)

MAC 2311	Calculus I	4
CHM 1045	General Chemistry I	3
CHM 1045L	General Chemistry I Lab	1
ENC 1101	Writing and Rhetoric I	3
BME 1008	Intro to Biomedical Engineering	2
BSC 1010	General Biology I	3
BSC 1010L	Gen Biology I Lab	1
SLS 1501	Freshman Experience	1

Second Semester: (17)

BME 1054L	Introduction to Biomedical Engineering Computing	1
MAC 2312	Calculus II	4
CHM 1046	General Chemistry II	3
CHM 1046L	Gen Chemistry II Lab	1
PHY 2048	Physics I w/ Calc	4
PHY 2048L	General Physics I Lab	1
ENC 1102	Writing and Rhetoric II	3

Third Semester: (17)

MAC 2313	Multi-variable Calculus	4
CHM 2210	Organic Chemistry I	4
CHM 2210L	Organic Chemistry I Lab	1
PHY 2049	Physics II w/ Calc	4
PHY 2049L	Physics II Lab	1
Humanities I	(Historical)	3

Fourth Semester: (15)

MAP 2302	Differential Equations	3
STA 3033	Intro Probability Statistics	3
BME 2740	BME Modeling & Simulation	3
Engineering or Science Elective		3
Humanities II	(Non-historical)	3

Fifth Semester: (17)

BME 3721	BME Data Evaluation Principles	3
BME 3403	Eng Analysis Biological Systems I	3
EEL 3110	Circuit Analysis	3
EEL 3110L	Circuits Lab	1
EGM 3503	Applied Mechanics	4
Social Inquiry I	(Foundations)	3

Sixth Semester: (17)

BME 3404	Eng Analysis Biological Systems II	3

EEE 4202C	Medical Inst Design	4
BME 4011	Clinical Rotations	1
Engineering or Science Elective		3
BME 3632	BME Transport	3
Social Inquiry II	(Societies & Identities)	3

Seventh Semester: (14)

BME 4050L	BME Lab I	1
BME 4100	Biomaterials Science	3
BME 4090	Design Project Organization	1
BME 4800	Design Biomedical Systems and Devices	3
Engineering or Science Elective		3
Art		3

Eighth Semester: (13)

BME 4051L	Biomed Lab II	1
BME 4908	Senior Design Project	3
Engineering or Science Elective		3
Engineering or Science Elective		3
Engineering or Science Elective		3
BME 4930	Undergraduate Seminar	0

Approved Science Electives*

CHM 2211	Organic Chemistry II
CHM 2211L	Organic Chemistry II Lab
BCH 3033	General Biochemistry I
BCH 3033L	General Biochemistry I Lab
CHM 4304	Biological Chemistry I
CHM 4304L	Biological Chemistry I Lab
MCB 3020	General Microbiology
MCB 3020L	General Microbiology Lab
PCB 3063	Genetics
PCB 3063L	Genetics Lab
PCB 4233	Immunology
PCB 4233L	Immunology Lab
PCB 4023	Cell Biology
PCB 4023L	Cell Biology Lab
PCB 4524	Molecular Biology
PCB 4524L	Molecular Biology Lab

Approved Electives for Tissue Engineering/Pre-Med*

BME 4332	Cell and Tissue Engineering
BME 4311	Molecular Imaging
EMA 3066	Polymer Science and Engineering
BME 4331	Introduction to Artificial Organs
Approved Science Electives	

Approved Electives for Biosignals and Systems*

BME 4401	Medical Imaging
BME 4562	Biomedical Optics
BME 4xxx	Biophysics of Neural Computation
EEL 3135	Signals and Systems
EEL 3657	Control Systems I
EEL 4510	Introduction to Digital Signal Processing

Approved Electives for Biomaterials and Biomechanics*

BME 4311	Orthopedic Biocmechanics
BME 4260	Engineering Hemodynamics
EGM 3311	Analysis of Engineering Systems
EGN 3365	Materials in Engineering
EML 3036	Sim Software for Mechanical Engineers
EML 4807	Introduction to Mechatronics

*Courses may be subject to prerequisites.

Minor in Biomedical Engineering

The minor requires 21 credit hours consisting of the following courses:

BSC 1010	General Biology I	3
BSC 1010L	General Biology I Lab	1
BME 3403	Eng Analysis Biological Systems I	3
BME 3404	Eng Analysis Biological Systems II	3
BME 4011	Clinical Rotations I	1
EEE 4202C	Med Instrumentation Design	4
BME 4800	Design Biomedical Systems and Devices	3
Biomedical Engineering Elective		3

Students majoring in electrical or mechanical engineering may apply the Minor towards a five-year accelerated combined degree program with the Master's degree in biomedical engineering.

Minor in Biomedical Engineering for Non-Engineering Majors

This minor program is designed for students who desire skills in addition to those developed in the basic sciences and is especially intended for biology and chemistry majors.

For admission to the minor, students need (1) To be fully admitted to their major; (2) To have a GPA ≥ 3.0.

To successfully complete the minor, a grade of "C" or better is required in all courses. The minor requires a minimum of 22 credit hours consisting of the following courses:

MAC 2313	Multivariable Calculus
MAP 3202	Differential Equations
BME 3404	Engineering Analysis of Biological Systems II
EGM 3503	Applied Mechanics
BME 3632	BME Transport
2 BME Electives	

Electives: The electives allow for the student to tailor their emphasis of study and must be one of the following two-course sequences:

EEL 3110	Circuit Analysis
	and
EEE 4202C	Med Instrumentation Design
	or
BME 4100	Biomaterials Science
	and
BME 4332	Cell and Tissue Engineering

Combined BS/MS Degree Programs

This five-year program seamlessly combines a baccalaureate degree in biomedical, mechanical or electrical engineering with the Master's in biomedical engineering. To be considered for admission to the combined bachelor's/master's degree program, students must have completed 75-90 credits in the bachelor's degree program at FIU, have earned at least a 3.25 GPA on both overall and upper division courses, and meet the admissions criteria for the graduate degree program to which they are applying. Students need only apply once to the combined degree program, but the application must be submitted to Graduate Admissions before the student starts the last 30 credits of the bachelor's degree program.

A student admitted to the combined degree program will be considered to have undergraduate status until the student applies for graduation from their bachelor's degree program. Upon conferral of the bachelor's degree, the student will be granted graduate status and be eligible for graduate assistantships. Students enrolled in the program may count up to 9 hours of graduate level courses (i.e., 5000 level or higher) as credits for both the undergraduate and graduate degree programs. For each of the courses counted as credits for both BS and MS degree, a minimum grade of 'B' is required. Upon completion of the combined BS/MS program, students must have accumulated a minimum of 24 hours of credits at the graduate (5000+) level. Students enrolled in the program are encouraged to seek employment with a department faculty member to work as student assistants on sponsored research projects.

Combined BS in Biomedical Engineering/MS in Engineering Management (BSBME/MSEM)

Students who pursue a BS degree and have completed 75~90 credits in the undergraduate program of Biomedical Engineering with an overall GPA of 3.2 or higher may, upon recommendation from three faculty members, apply to the department to enroll in the combined BSBME/MSEM program. Students must also submit an online application to the University Graduate School for admission to the MSEM program. In addition to the admission requirements of the MSEM program, students must meet all the admission requirements of the University Graduate School.

Students need only apply once to the combined degree program, but the application must be submitted to Graduate Admissions before the student starts the last 30 credits of the bachelor's degree program. A student admitted to the combined degree program will be considered to have undergraduate status until the student applies for graduation from their bachelor's degree program. Upon conferral of the bachelor's degree, the student will be granted graduate status and be eligible for graduate assistantships.

Students enrolled in the combined degree program could count up to three BME graduate courses for both the BSBME electives and the MSEM electives, for a total saving of 9 credit hours. The following is a list of eligible BME graduate courses:

BME 5005	Applied Biomedical Engineering Principles	3
BME 5036	Biotransport Processes	3
BME 5105	Intermediate Biomaterials Science	3
BME 5316	Molecular Bioprocess Engineering	3
BME 5340	Introduction to Cardiovascular Engineering	3
BME 5560	Biomedical Engineering Optics	3
BME 5573	Nanomedicine	3

The combined BSBME/MSEM program has been designed to be a continuous program. During this combined BSBME/MSEM program, upon completion of all the requirements of the BSBME program, students will receive their BSBME degree. Students may elect to permanently leave the combined program and earn only the BSBME degree. Students who elect to leave the combined program and earn only the BS degree will have the same access requirements to regular graduate programs as any other student, but will not be able to use the 9 credit hours in both the BSBME and MSEM degrees.

For each of the graduate courses counted as credits for both BSBME and MSEM degrees, a minimum grade of "B" is required. Only graduate courses with formal lecture can be counted for both degrees. The students are responsible for confirming the eligibility of each course with their undergraduate advisors.

Students interested in the combined program should consult with their undergraduate advisor on their eligibility to the program. The student should also meet the MSEM Program Director to learn about the graduate program and available tracks/courses before completing the application form and submitting it to their undergraduate advisor. Final decision for admission to the MSEM program will be made by the University Graduate School upon recommendation by the Engineering Management program director. Applicants will be notified by the Engineering Management Program and the University Graduate School of the decision on their applications.

Course Descriptions

Definition of Prefixes

BME-Biomedical Engineering; EEE-Engineering: Electrical and Electronics; EEL-Electrical Engineering

Courses that meet the University's Global Learning requirement are identified as GL.

BME 1008 Introduction to Biomedical Engineering (2). This course will provide a broad view of biomedical engineering and introduce the sub-areas within the field. Students will be provided with the history, current status and the future of the field.

BME 1054L Introduction to Biomedical Engineering Computing (1). Introduction to computers for biomedical engineers. Basic computer programming principles and introduction to computer software such as MATLAB and Labview.

BME 2740 Biomedical Engineering Modeling and Simulation (3). Computer modeling of biomedical applications. Extensive use of Matlab and Simulink for modeling and analysis of biomedical phenomena. Prerequisites: BSC 1010 (with a grade of "C" or better), BME 1054L. Corequisites: MAP 2302, BME 1008.

BME 3403 Engineering Analysis of Biological Systems I (3). A quantitative, model approach to physiological systems at the cellular and tissue level. Thermodynamic, biochemical and biophysical principles of the cell, general system anatomy and functionality. Prerequisites: BME 2740, PHY 2049 (with a "C" or better), CHM 2210 (with a "C" or better).

BME 3404 Engineering Analysis of Biological Systems II (3). Quantitative description of physiological systems at the integrative systems level. Includes engineering analysis relating design to organ function. Prerequisite: BME 3403.

BME 3632 Biomedical Engineering Transport (3). Basic principles of heat, mass, and fluid transport. Derivation of basic equations, and simplification techniques. Applications to physiological systems, artificial organs, and pharmacokinetics. Prerequisites: BME 2740, EGM 3503, CHM 1046 (with a grade of "C" or better), MAP 2302 (with a grade of "C" or better), PHY 2049 (with a grade of "C" or better). Corequisite: MAC 2313.

BME 3721 Biomedical Engineering Data Evaluation Principles (3). Design and analysis of clinical and biomedical experiments. Statistical process control and measuring performance relevant to medical device industry. Prerequisites: (STA 3033 or EIN 3235).

BME 4007 Principles of Bioengineering – *GL* (3). Medical instrumentation and design, regulations for medical devices, application of computers in medicine, biomaterials, biocommunications, artificial implants; clinical engineering. Prerequisites: BME 3403 or permission of the instructor.

BME 4011 Clinical Rotations for Biomedical Engineering (1). Clinical lectures, video presentations, and observational and participatory rotations through various divisions and laboratories at BME's clinical and industrial partners. Prerequisites: BME 3403 or permission of the instructor. Corequisite: BME 3404.

BME 4050L Biomedical Engineering Lab I (1). Design, implementation and analysis of biomedical experiments, including biomechanics, tissue mechanics, fluid transport, cardiovascular hemodynamics and materials for artificial organs and implants. Prerequisites: BME 3721, EEL 3110. Corequisites: BME 3632, BME 4100.

BME 4051L Biomedical Engineering Lab II (1). Design, implementation and analysis of biomedical experiments, including bio-signal data acquisition, processing and analysis, mass transport and medical image processing and interpretation. Prerequisites: BME 3721, EEL 3110. Corequisites: BME 4100, BME 3632.

BME 4090 Design Project Organization (1). Organization for capstone project, project feasibility study, proposal writing, oral communications, professional ethics, project management. Prerequisite: EEE 4202C. Corequisite: BME 4800.

BME 4100 Biomaterials Science (3). Materials used in prosthesis for skin and soft tissue, vascular implant devices, bone repair, and artificial joints. Structure-property relationships for biological tissue. Prerequisite: EGM 3503. Corequisite: BME 3404.

BME 4211 Orthopedic Biomechanics (3). Introduction to the fundamentals of human musculoskeletal physiology and anatomy and computation of mechanical forces as it applies to orthopaedic biomechanics. Prerequisite: BME 4100.

BME 4230 Biomechanics of Cardiovascular Systems (3). Functional cardiovascular physiology and anatomy; analysis and computation of cardiovascular flow; constitutive properties of tissue; coronary and systemic circulation; flow and stress considerations in cardiovascular assist devices. Prerequisites: BME 3632, BME 3404, and BME 4100.

BME 4260 Engineering Hemodynamics (3). Fluid mechanics of the circulatory system, rheology of blood, lubrication mechanics. Prerequisites: BME 3632, BME 3404.

BME 4311 Molecular Engineering (3). The aim of this course is to educate students in the area of biomedical engineers and interested engineering students with molecular biology, genetic engineering and proteomic engineering. Prerequisite: BME 3403.

BME 4331 Introduction to Artificial Organs (3). An introduction to theoretical and experimental models of artificial organs for drug delivery, extracorporeal devices, oxygenators, tissue engineered models of organs, computer simulations of fluid and mass transport. Prerequisite: BME 4332.

BME 4332 Cell and Tissue Engineering (3). Physiology of cell growth and in vitro cultivation with basic techniques in biotechnology. Analysis of fundamental processes and engineering approaches on in vitro models for tissue growth. Prerequisites: MAC 2313 (with a grade of "C" or better), BME 3632, BME 4100.

BME 4422 The Biophysics of Neural Computation (3). This course provides an introduction to the working principles of neurons and neural circuits with emphasis on mathematical models. Prerequisite: Permission of the instructor.

BME 4503C Medical Instrumentation: Application and Design (4). Concepts of transducers and instrumentation systems; origins of biopotentials; electrical safety; applications of medical instrumentation. Prerequisite: EEL 3110.

BME 4531 Medical Imaging (3). Fundamentals of major imaging modalities including x-ray radiology, x-ray computed tomography, ultrasonography, magnetic resonance imaging, nuclear imaging (PET and SPECT), and optical imaging. Prerequisites: PHY 2049 and BME 2740.

BME 4562 Introduction to Biomedical Optics (3). Fundamentals of biomedical optics, covering optical spectroscopy, polarimetry, and interferometry. Engineering principles used in optical diagnostics, biosensing and therapeutics. Prerequisites: PHY 2049 and BME 3403.

BME 4730 Analysis of Self-Regulation and Homeostasis in Biosystems (3). Application of quantitative analysis methods to the study of self regulation processes that result in homeostatic conditions in biosystems with special emphasis on processes found in the human body. Prerequisites: BME 3404, EEE 4202C.

BME 4800 Design of Biomedical Systems and Devices (3). Mechanical design and material choices of various biomedical systems and devices such as cardiovascular assist devices, total artificial heart, pulmonary assist devices, total hip prosthesis and other orthopedic devices. Prerequisites: BME 3721, BME 4011. Corequisite: BME 3632.

BME 4908 Senior Design Project (3). Customer needs; design requirements; biocompatibility; regulatory, ethical, societal, and environmental considerations; creativity; project management; prototype construction and testing; final report and presentation. Prerequisite: BME 4090.

BME 4912 Undergraduate Research in Biomedical Engineering (1-3). Participate in supervised research activities on current biomedical engineering topics under the direction of a BME faculty member.

BME 4930 Undergraduate Seminar (0). The course consists of oral presentations made by guests, faculty and students on current topics and research activities in Biomedical Engineering.

BME 4931 BME Special Topics/Projects (1-3). Individual conferences, assigned readings, and reports on independent investigations selected by students and professor with approval of the advisor. Prerequisite: Permission of the instructor.

BME 4940 Undergraduate Internship in Biomedical Engineering (1-3). Engineering practice in biomedical applications in device manufacturing, research and development, healthcare delivery or a related area. Interns will be required to submit a pre-semester objective to the Biomedical Engineering Academic Advisor, as well as a final report and evaluation that must be completed and approved by the internship supervisor.

BME 4949 Biomedical Engineering CO-OP (1-3). Engineering practice in biomedical applications at an industrial partner's site. Intern will be hired through a cooperative agreement to conduct collaborative research with supervision of advisor.

BME 5005 Applied Biomedical Engineering Principles (3). Biomedical engineering applications to instrumentation, transport phenomena, mechanics, materials and imaging. Prerequisite: Permission of the instructor.

BME 5036 Biotransport Processes (3). Transport of fluid, heat, and mass in the human body. Application to dialyzers and heart-lung devices. Prerequisites: BME 3632, BME 4100.

BME 5105 Intermediate Biomaterials Science (3). Materials used in prosthesis for skin and soft tissue, vascular implant devices, bone repair, and artificial joints. Structure-property relationships for biological tissue. Prerequisite: Permission of the instructor.

BME 5316 Molecular Bioprocess Engineering (3). Use of enzyme kinetics, bioreactor design, bioseparations and bioprocessing in the biomedical, biopharmaceutical, and biotechnology industries. Prerequisites: BCH 3033, BME 3632.

BME 5340 Introduction to Cardiovascular Engineering (3). Quantitative cardiovascular physiology, engineering applied to cardiovascular system: mechanics, materials, transport, and design.

BME 5350 Radiological Engineering and Clinical Dosimetry (3). Quantities for describing the interaction of radiation fields with biological systems. Absorption of radiant energy by biological systems. Applications to clinical dosimetry and radiation safety procedures. Prerequisite: Permission of the instructor.

BME 5358L Clinical Rotation in Radiation Oncology (3). Practical calibration of radiation therapy instruments, dose calculation and planning of radiation treatment under supervision of certified medical physicist. Prerequisite: BME 5505C.

BME 5410 Biomedical Physiology and Engineering I (3). Introductory course on cardiovascular and respiratory physiology and associated engineering concepts frequently encountered in the Biomedical Engineering field.

BME 5411 Biomedical Physiology and Engineering II (3). Introductory course on neural and musculoskeletal physiology and associated engineering concepts frequently encountered in the Biomedical Engineering field.

BME 5505C Engineering Foundation of Medical Imaging Instrument (3). Engineering basis of medical imaging systems, including radiology, X-Ray CT, SPECT, PET, MRI, and laser and ultrasound based imaging, as well as instrument quality assurance procedures. Prerequisite: Permission of the instructor.

BME 5560 Biomedical Engineering Optics (3). Introduction to physical and geometrical optics of biomedical optical devices. Design of optical microscopes, endoscopes, fiber optic delivery systems, spectrometers, fluorometers, and cytometers. Prerequisites: Calculus, Differential Equations, Chemistry, and Physics.

BME 5573 Nanomedicine (3). Nano-scale tools and nanomaterials that result in new medical products and applications with special emphasis on imaging, diagnosis, drug delivery, regenerative medicine as well as new biomaterials. Prerequisites: BME 5105 or permission of the instructor.

BME 5726 Protein Engineering (3). Cloning, expressing and purifying proteins, and E. coli and yeast expression systems. Design of proteins for specific end uses. Prerequisite: Permission of the instructor.

BME 5731 Analysis of Physiological Control Systems (3). Quantitative analysis methods and modeling of the self-regulation processes that result in homeostatic conditions in physiological systems with special emphasis on processes found in the human body. Prerequisites: Permission of the instructor, EEL 3110, BME 3404.

BME 5803 Biomedical Device Design and Ethics (3). User inputs; regulatory, ethical, societal, and environmental considerations; creativity; project management; prototype construction and testing; project feasibility; writing and oral communication. Prerequisite: Permission of the instructor.

BME 5941 Biomedical Engineering Internship (1-3). Engineering practice in biomedical applications at an industrial partner's site. Intern will be hired through cooperative agreement to conduct collaborative research with supervision of advisor.

EEE 4202C Medical Instrumentation Design (4). Concepts of transducers and instrumentation systems; origins of biopotentials; electrical safety; therapeutic and prosthetic devices. Prerequisite: EEL 3110.

EEE 5261 Bioelectrical Models (3). Engineering models for electrical behavior of nerve and muscle cells, electrode-tissue junctions, volume conductions in tissue and the nervous system as an electrical network. Prerequisites: EEE 4202C or permission of the instructor.

EEE 5275 Bioradiation Engineering (3). Spectrum of radiation sources, types of fields, properties of living tissue, mechanisms of field propagation in tissue. Applications in imaging and therapy, hazards and safety. Prerequisites: EEL 4410 or permission of the instructor.

EEL 4510 Introduction to Digital Signal Processing (3). Z transform and digital filters. Design of digital filters. Effects of finite register length in digital filters. Engineering applications of digital filters. Prerequisites: EEL 3514 or permission of the instructor. Corequisites: EEE 4314 or permission of the instructor.

EEL 5820 Digital Image Processing (3). Image Fundamentals, Image Transforms, Image Enhancement, Edge Detection, Image Segmentation, Texture Analysis, Image Restoration, and Image Compression. Prerequisites: EEL 3135 and knowledge of any programming language (FORTRAN, Pascal, C). (F)