Biomedical Engineering

**BMEN 1100** Introduction to Bioengineering I (1 semester credit hour) This is a laboratory course emphasizing the essential skills and tools necessary to succeed in a biomedical engineering degree plan. Three core areas of the field will be introduced - biochemistry, solid mechanics, and bioelectronics. Lab activities will include statistical analysis of a biochemical transport problem, understanding and fabricating mechanical devices based on engineering drawings, and assembling and testing simple electronic circuits to record and analyze bioelectrical signals of the human body. CE 1100 or CS 1200 or EE 1100 or MECH 1100 can substitute for this course. Credit cannot be received for more than one of the following: BMEN 1100, CE 1100, CS 1200, EE 1100 or MECH 1100. (0-3) Y

**BMEN 1208** Introduction to Bioengineering II (2 semester credit hours) Project-based instruction. The purpose of this course is to give students a general understanding of the broad range of applications specific to the biomedical engineering profession. Course exercises include team-oriented competitions, lectures by various external biomedical engineering experts, and introductory materials associated with the discipline. Perform a competitive team design project. Prerequisite: BMEN 1100. Prerequisites or Corequisites: (PHYS 2325 and PHYS 2125) and (MATH 2419 or MATH 2414). (1-2) Y

**BMEN 2320** Statics (3 semester credit hours) Lecture course. Course material includes vector representations of forces and moments, free body diagrams, equilibrium of particles, center of mass, centroids, distributed load systems, equivalent force systems, equilibrium of rigid bodies, trusses, frames and machines, internal forces in structural members, shear forces and bending moments in beams, friction, area and mass moments of inertia, the principle of virtual work. Prerequisites: PHYS 2325 and PHYS 2125. Prerequisites or Corequisites: MATH 2415 or MATH 2419 or equivalent. (3-0) S

**BMEN 2V99** Topics in Biomedical Engineering (1-4 semester credit hours) May be repeated as topics vary (9 semester credit hours maximum). ([1-4]-0) R

**BMEN 3110** Biomedical Transport Processes Laboratory (1 semester credit hour) Laboratory course. Prerequisite: RHET 1302. Prerequisite or Corequisite: BMEN 3310. (0-3) Y

**BMEN 3120** Biomedical Circuits and Instrumentation Laboratory (1 semester credit hour) Laboratory course. This course will include a brief recitation (discussion) session prior to each lab. Prerequisite or Corequisite: BMEN 3320. Prerequisite: RHET 1302. (0-3) Y

**BMEN 3130** Engineering Physiology Laboratory (1 semester credit hour) Laboratory course. Prerequisite: RHET 1302. Prerequisite or Corequisite: BMEN 3330. (0-3) Y

**BMEN 3150** Biomedical Engineering Laboratory (1 semester credit hour) Laboratory course. Prerequisite or Corequisite: BMEN 3350. Prerequisite: RHET 1302. (0-3) Y

**BMEN 3170** Digital Circuits Laboratory (1 semester credit hour) Laboratory Course. Prerequisite: BMEN 3370. (0-3) Y

**BMEN 3310** Fluid Mechanics and Transport Processes in Biomedical Engineering (3 semester credit hours) Introduction to fluid flow and transport phenomena in bioengineering. Fluids in biological circulatory systems, devices, and microsystems. Mass, thermal, and multiphase transport in biology. Emphasis on the use of mathematical modeling and computer simulations. Prerequisites: BMEN 1208 and ENGR 3300. (3-0) Y

**BMEN 3315** Thermodynamics and Physical Chemistry in Biomedical Engineering (3 semester credit hours) An introduction to the fundamentals of thermodynamics and physical chemistry. Molecules and chemical bonds, chemical kinetics and reaction equilibria. Topics also include molecular transitions, nonequilibrium processes, self assembly, and interface thermodynamics.
Credit cannot be received for both courses, BMEN 3315 and BMEN 3360. Prerequisites: (CHEM 1301 or (CHEM 1311 and CHEM 1312)) and (CHEM 2324 or (CHEM 2323 and CHEM 2325)) and (MATH 2415 or MATH 2419 or equivalent) and (PHYS 2126 and PHYS 2326). (3-0) Y

BMEN 3320 Electrical and Electronic Circuits in Biomedical Engineering (3 semester credit hours) Introduction to analysis methods and network theorems used to describe operation of electric circuits. Electrical quantities, linear circuit elements, circuit principles, signal waveforms, transient and steady state circuit behavior, diode and transistor circuits, operational amplifiers, digital logic devices. Time domain and Laplace transform methods for analysis of electric circuits. Modeling, analysis and simulation of circuits. It is recommended that students take BMEN 3120 with this course. Prerequisites: MATH 2420 and (PHYS 2126 and PHYS 2326). Prerequisite or Corequisite: CS 1324. (3-0) Y

BMEN 3325 Advanced Computational Tools for Biomedical Engineering (3 semester credit hours) MATLAB is an increasingly important tool for solving data-driven Bioengineering/Biomedical Engineering (BE/BME) problems. MATLAB is both a programming language and a platform with toolboxes for data acquisition, processing, visualization, analysis, as well as simulation. This course will provide an extensive training on how to use these advanced engineering tools in MATLAB. These tools could work either with hardware or as independent software. Advanced topics in programming and programming skills for solving biomedical problems. Advanced topics in programming and computational models will be introduced in lectures. Class assignments, home assignments, and class projects will be used for practice and training. The course will help students to be better prepared for their junior, senior, graduate study, or professional work. Prerequisite: BMEN 1208. (1.5-1.5) Y

BMEN 3330 Engineering Physiology of the Human Body (3 semester credit hours) An introduction to the physiology of the human body for engineers. This course will cover the various levels of structural organization of the body, from molecular, cellular and tissue/organ organization to the whole body anatomy and maintenance. Students will learn to apply engineering tools and concepts to understand normal and abnormal physiology. It is recommended that students take BMEN 3130 with this course. Prerequisite: BIOL 2311. (3-0) S

BMEN 3335 Biomedical Component and System Design (3 semester credit hours) Fundamental knowledge behind design of biomedical systems. Design and implementation of biomedical signal processing. Modeling and simulation for biomedical systems. Circuit and system design method for implantable devices. Software and hardware infrastructure for biomedical applications. Computer-aided techniques for analyzing sampled data. It is recommended that students take BMEN 3150 with this course. Prerequisite: BMEN 3320. Prerequisite or Corequisite: EE 3302. (3-0) Y

BMEN 3360 Thermodynamics (3 semester credit hours) This course focuses on introductory concepts and definitions of thermodynamics, energy, and the availability of reversible work, machine, and cycle processes; real gas behavior; first law of thermodynamics, phase-change, internal energy, energy balance, entropy, ideal gas, control volume analysis, second law of thermodynamics, vapor, gas, and refrigeration power systems. Credit cannot be received for both courses, BMEN 3315 and BMEN 3360. Prerequisites: ENGR 3300 and PHYS 2325. Prerequisites or Corequisites: CHEM 1301 or (CHEM 1311 and CHEM 1312) and CHEM 2324 or (CHEM 2323 and CHEM 2325). (3-0) S

BMEN 3370 Digital Circuits (3 semester credit hours) Digital circuit design, hardware structures, and hardware description language concepts that underlie the design of modern computer systems and their application to biomedical electronics. Topics include: internal data representation and arithmetic operations in a computer, Boolean logic, combinational logic circuits and sequential circuits. Design of arithmetic circuits, shifters and counters. Design and analysis of synchronous state machines. Hands-on laboratory experiments to design and analyze logic circuits using SSI, MSI and FPGAs. Use of Verilog to design and test circuits.

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Prerequisites: MATH 2420 and (PHYS 2126 and PHYS 2326). (3-0) Y
BMEN 3380 Medical Imaging Systems and Methods (3 semester credit hours) In this course, the fundamental physical principals of modern medical imaging techniques will be covered, including x-ray, ultrasound, MRI, optical, and nuclear imaging. Emphasis will also be placed on imaging contrast agents, image processing, and multi-modality imaging. Prerequisite: EE 3302. (3-0) Y
BMEN 3399 Introductory Biomechanics (3 semester credit hours) The course covers both biosolid and biofluid mechanics. Covered topics include kinematics, stress, strain, equilibrium, extension, and torsion. Topics will be discussed in the context of biomedical engineering tools and biological tissue structure, function, and properties. Biofluid mechanics concepts will include stress, motion, balance relations (balance of mass, and balance of linear momentum), and their constitutive relations as well as flow between parallel plates and circular tubes. The latter lay the foundation for understanding fluid flow in the human body. Practical examples within the human body including examples of bone and artery loading mechanics will be incorporated. Selected basic concepts in biomaterials will be introduced in the context of biomechanical applications. Prerequisite: BMEN 2320. (3-0) R
BMEN 3402 Signals and Systems for Biomedical Engineering (4 semester credit hours) In this course, fundamentals of continuous and discrete-time signal processing are introduced. The main time and frequency-domain concepts covered in the course are convolution, impulse response, Fourier transform, and sampling theorem. The course also acquaints students with signal processing in MATLAB. Credit cannot be received for more than one of the following: BM EN 3402 or CE 3302 or EE 3302 or TE 3302. Prerequisite: ENGR 3300. (4-0) Y
BMEN 3V99 Topics in Biomedical Engineering (1-4 semester credit hours) May be repeated as topics vary (9 semester credit hours maximum). Instructor consent required. ([1-4]-0) R
BMEN 4110 Biomedical Feedback Systems Laboratory (1 semester credit hour) Laboratory course. Corequisite: BMEN 4310. Prerequisite: RHET 1302. (0-3) Y
BMEN 4310 Feedback Systems in Biomedical Engineering (3 semester credit hours) Notions of inputs, outputs, and states. Linearity versus nonlinearity. Deterministic versus stochastic systems. Top down versus bottom up modeling. Sensitivity and reduction of sensitivity via feedback. Introduction to stability. Feedback for stabilization and disturbance rejection. Numerical simulation and controller design via computational approaches. It is recommended that students take BMEN 4110 with this course. It is strongly recommended that students take this course prior to BMEN 4388. Prerequisites: ENGR 2300 and MATH 2420. (3-0) Y
BMEN 4320 Intermediate Electrical Systems (3 semester credit hours) Principles of circuit and system analysis methods used in the design and analysis of biomedical instrumentation. Circuit solution methods. Filter design methods. Special emphasis is placed on circuits commonly employed in biomedical devices, such as amplifiers and filtering networks used in electrocardiograph systems, construction and characterization of simple transducers and signal conditioning equipment for measuring biomedical parameters such as force, displacement, pressure, flow and biopotentials. Prerequisites: BMEN 3120 and BMEN 3320. (3-0) Y
BMEN 4342 Introduction to Robotics (3 semester credit hours) Fundamentals of robotics, rigid motions, homogeneous transformations, forward and inverse kinematics, velocity kinematics, motion planning, trajectory generation, sensing, vision, and control. Prerequisite or Corequisite: BMEN 4310 or EE 4310 or MECH 4310 or equivalent. (Same as EE 4342 and MECH 4342) (2-3) Y
BMEN 4350 Applied Sensor Technology (3 semester credit hours) Introduction to the basic principles and design issues of biomedical sensors and instrumentation, including: the physical principles of biomedical sensors, analysis of biomedical instrumentation systems, and the application-specific biomedical sensor and instrumentation design. Topics include: basic concepts of sensors and instrumentation, membrane biophysics, action potentials, biopotential
electrodes. Prerequisites: (BMEN 3320 and BMEN 3120) and (BMEN 3330 and BMEN 3130). (3-0) Y

BMEN 4355 Finite Element Analysis in Biomedical Engineering (3 semester credit hours) The course will provide an introduction to the finite element method with an emphasis on applications in biomedical engineering. Traditionally rooted in structural engineering, finite element methods are used in simulating the mechanical response of the human body and medical devices. Theories will be reinforced through practical applications primarily using commercial simulation software. The course will also briefly cover methods of creating computational models from medical image sets. Prerequisites: (BMEN 3399 and ENGR 2300) or (senior status and permission of instructor). (3-0) Y

BMEN 4360 Biomaterials and Medical Devices (3 semester credit hours) Introduction to the field of biomaterials used in the design and engineering of medical devices, and to augment or replace soft and hard tissues. Discussion of bulk properties, applications, and in vivo behavior of different classes of natural and synthetic biomaterials. Analysis of biological response and biocompatibility, degradation and failure processes of implantable biomaterials/devices. Overview of regulatory compliance and performance requirements for commercialization of biomaterials and medical devices. Prerequisites or Corequisites: BMEN 2320 and (CHEM 1301 or CHEM 1311 and CHEM 1312) and (CHEM 2324 or CHEM 2323 and CHEM 2325). (3-0) Y

BMEN 4370 Biomedical Image Processing (3 semester credit hours) This course covers basic digital image processing techniques used for the analysis of biomedical images. Topics include a general introduction to the various biomedical imaging modalities, digital image fundamentals, intensity transformations, spatial and frequency domain filtering, image restoration and reconstruction, color image processing, image segmentation, and 3D data visualization. A large percentage of the course grade is based on laboratory exercises, which require students to program image processing techniques using MATLAB and apply them to digital images. Prerequisites: BMEN 3402 and experience with MATLAB Programming. (3-0) Y

BMEN 4388 Senior Design Project I (3 semester credit hours) First of two sequential semesters devoted to a team project that engages students in the full engineering design process. The goal of senior design projects is to prepare the student to run/participate in engineering projects related to an appropriate industry. Thus, all project teams are to follow standard industrial practices and methods. Teams must carry the engineering project to completion, examining real world and multiple design constraints, following applicable industrial and business standards. Such constraints may include but are not limited to: economic, environmental, industrial standards, team time/resource management and cross-disciplinary/departmental result integration. Students are required to work in teams that include collaborative design interaction. Additionally, cross-disciplinary/departamental teams are encouraged but not required. In Senior Design I, project proposals will be written, reviewed and approved. Initial designs will be completed and corresponding constraints will be determined. All students will participate in a public oral and poster presentation following departmental approved guidelines at a departmental approved time and location. Teams will also submit a written end of semester progress report and documented team communication (complete sets of weekly reports and/or log books) following guidelines approved by the faculty. It is strongly recommended that students take BMEN 4310 prior to this course. Prerequisites: BMEN 3130 and BMEN 3150 and BMEN 3320 and BMEN 3330 and BMEN 3350 and ECS 3390. (3-0) Y

BMEN 4389 Senior Design Project II (3 semester credit hours) Continuation of the Senior Design project begun in the previous semester. In Senior Design II, projects based on approved project proposals will be completed. All limitations of the design will be determined and addressed. All students will participate in a public oral presentation following faculty-approved guidelines at a faculty-approved time and location. Teams will also submit a written final report and documented team communication (complete sets of weekly reports and/or log books)
following faculty-approved guidelines. Prerequisite: **BMEN 4388**. (3-0) Y

**BMEN 4399** Senior Honors in Biomedical Engineering (3 semester credit hours) For students conducting independent research for honors theses or projects. Instructor consent required. (3-0) R

**BMEN 4V95** Undergraduate Topics in Biomedical Engineering (1-6 semester credit hours) For organized classes only (not for individual instruction). Subject matter will vary from semester to semester. May be repeated for credit as topics vary (6 semester credit hours maximum). Instructor consent required. Student must document School of Engineering content via a written report. ([1-6]-0) R

**BMEN 4V97** Independent Study in Biomedical Engineering (1-6 semester credit hours) Independent study under a faculty member's direction. Student must document School of Engineering content via a written report. May be repeated for credit as topics vary (6 semester credit hours maximum). Instructor consent required. ([1-6]-0) R

**BMEN 4V98** Engineering Practicum (1-6 semester credit hours) This course may be used as an honors course. Student must document School of Engineering content via a written report. May be repeated for credit as topics vary (6 semester credit hours maximum). Instructor consent required. ([1-6]-0) R