

# BMEN - BIOMEDICAL ENGINEERING (BMEN)

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## **BMEN 153 Pathways in Biomedical Engineering**

**Credit 1. 1 Lecture Hour.**

Overview of biomedical engineering and the biomedical engineering industry, including specialties, degree requirements and scholastic programs in the Department of Biomedical Engineering.

**Prerequisite:** Biomedical Engineering major.

## **BMEN 207 Computing for Biomedical Engineering**

**Credits 3. 2 Lecture Hours. 3 Lab Hours.**

Introduction to the principles of computer programming for biomedical applications including program design and development, programming techniques and documentation; introduction to and programming in the Python and LabVIEW environments.

**Prerequisite:** Admitted to major degree sequence; grade of C or better in MATH 152, and ENGR 102 or ENGR 112.

## **BMEN 211 Biomedical Applications of Signals and Systems**

**Credits 3. 3 Lecture Hours.**

Quantitative analysis of biomedical and physiological signals; Fourier and Laplace transforms; filtering of biomedical signals; electrical circuits and analog representations of physiological systems as model systems; A/D conversion and sampling.

**Prerequisites:** Admitted to major degree sequence; PHYS 207 or PHYS 208; MATH 308 or concurrent enrollment.

## **BMEN 253 Medical Device Design I**

**Credit 1. 3 Lab Hours.**

FDA design controls for medical device development in a regulated environment; small-scale team biomedical engineering design project.

**Prerequisite:** Grade of C or better in BMEN 153 or concurrent enrollment; Biomedical Engineering major or minor.

## **BMEN 285 Directed Studies**

**Credits 0 to 4. 0 to 4 Other Hours.**

Allows students to undertake special projects in biomedical engineering at an earlier point in their studies than required for BMEN 485.

**Prerequisite:** Approval of Director of Undergraduate Programs.

## **BMEN 289 Special Topics in...**

**Credits 1 to 4. 1 to 4 Lecture Hours. 0 to 4 Lab Hours.**

Selected topics in an identified area of biomedical engineering. May be repeated for credit.

**Prerequisite:** Approval of instructor.

## **BMEN 291 Research**

**Credits 0 to 4. 0 to 4 Other Hours.**

Research conducted under the direction of faculty member in biomedical engineering. May be repeated 2 times for credit.

**Prerequisites:** Freshman or sophomore classification and approval of instructor.

## **BMEN 305 Bioinstrumentation**

**Credit 1. 3 Lab Hours.**

Introduction to biomedical instrumentation design; hands on acquisition of biomedical signals; design, building and testing of bioinstrumentation circuits including analog signal amplifiers and analog filter circuits.

**Prerequisite:** Grade of C or better in BMEN 211; grade of C or better in BMEN 321 or concurrent enrollment.

## **BMEN 321 Biomedical Electronics**

**Credits 3. 3 Lecture Hours.**

Introduction to biomedical signals; basic circuit analysis for biomedical signals; design of bioamplifier circuits; characteristics of linear and nonlinear circuit elements; design of basic electronic circuits, principles and practice of bioelectronic measurements.

**Prerequisites:** Grade of C or better in BMEN 211; junior or senior classification; Biomedical Engineering major or minor.

## **BMEN 322 Biosignal Analysis**

**Credits 3. 3 Lecture Hours.**

Design and application of analog and digital signal analysis in biomedical engineering; characteristics of biomedical signals; design considerations for analog-to-digital and digital-to-analog circuitry; biosignal transformation methods; analog and digital filter design for biomedical signals.

**Prerequisite:** BMEN 321.

## **BMEN 341 Biofluid Mechanics**

**Credits 3. 3 Lecture Hours.**

Introduction into the mechanics of fluids in biomechanics, including blood, synovial fluid and physiological solutions, with an emphasis on the importance of mechanobiology and the formation of biological problems within the context of 1) kinematics, 2) the concept of stress, 3) linear momentum balance, 4) constitutive relations, and 5) boundary conditions.

**Prerequisites:** MATH 308; Biomedical Engineering major or minor; junior or senior classification.

## **BMEN 343 Introduction to Biomaterials**

**Credits 3. 3 Lecture Hours.**

Properties of natural and man-made materials commonly encountered in biomedicine and biomedical engineering; an integrated approach in the presentation of material structures, characteristics and properties; the basics of material structures, including crystalline and chemical structure, and microstructure; and bulk properties and characteristics of the materials developed from the microscopic origins.

**Prerequisites:** MATH 308 and CHEM 227; Biomedical Engineering major or minor; junior or senior classification.

## **BMEN 344 Biological Responses to Medical Devices**

**Credits 3. 3 Lecture Hours.**

Selection and characterization of materials in implantable and tissue contacting medical devices; biodegradation, biocompatibility, hemocompatibility and cell-material interactions of biomaterials.

**Prerequisite:** Grade of C or better in BMEN 343; grade of C or better in BMEN 345 or concurrent enrollment; VTPP 435 or concurrent enrollment; biomedical engineering major or minor.

## **BMEN 345 Biomaterials Lab**

**Credit 1. 3 Lab Hours.**

Experimental methods used to prepare and characterize polymeric biomaterials used in biomedical engineering; related fundamental aspects of forming a hypothesis, experimental design, empirical observation, data collection, interpretation and presentation of data.

**Prerequisite:** Grade of C or better in BMEN 343; grade of C or better and concurrent enrollment in BMEN 350.

**BMEN 350 Statistics for Biomedical Engineering****Credits 3. 3 Lecture Hours.**

Evaluation of the efficacy of clinical research; quantitative methods used in clinical trials in biomedical engineering; ethical and regulatory issues that must be considered during the design and implementation of any clinical trial, or pre-clinical study.

**Prerequisites:** Junior classification; admitted to the major degree sequence (upper level).

**BMEN 353 Medical Device Design II****Credit 1. 3 Lab Hours.**

Identification of needs for biomedical engineering design solutions, development of design proposals, analysis of design project requirements and constraints.

**Prerequisite:** Grade of C or better in BMEN 253 or equivalent; junior or senior classification.

**BMEN 361 Biosolid Mechanics****Credits 3. 3 Lecture Hours.**

Introduction to the mechanics of deformable media in biomedical engineering, including medical devices, biomaterials, and soft and hard biological tissues: emphasis on biomechanics and mechanobiology and formulation of problems within the context of basic continuum biomechanics; problems include analytical solutions for stress-strain analysis of extension, distension, bending, buckling, and torsion of biosolids.

**Prerequisites:** MATH 308; Biomedical Engineering major or minor; junior or senior classification.

**BMEN 399 Engineering Professional Development****Credits 0. 0 Other Hours.**

Participation in an approved high-impact learning practice; reflection on professional outcomes from engineering body of knowledge; documentation and self-assessment of learning experience at mid-curriculum point.

**Prerequisites:** Admission to biomedical engineering; junior or senior classification or approval of instructor.

**BMEN 400/VTPP 401 History of Human and Veterinary Medicine in Europe****Credits 4. 4 Lecture Hours.**

Addresses the major developments in human and veterinary medicine in Europe from the Middle Ages to the present; explores key events and figures in medical history and analyzes issues of current biomedical concern in a historical context; for example, animal rights, ethics of humane experimentation, euthanasia.

**Prerequisites:** Admitted to major degree sequence in biomedical engineering; VTPP 434.

**Cross Listing:** VTPP 401/BMEN 400.

**BMEN 401 Principles and Analysis of Biological Control Systems****Credits 3. 3 Lecture Hours.**

Techniques for generating quantitative mathematical models of physiological control systems and devices; the behavior of physiological control systems using both time and frequency domain methods.

**Prerequisite:** BMEN 321.

**BMEN 402 Biomedical Optics Laboratory****Credits 3. 2 Lecture Hours. 3 Lab Hours.**

Biomedical optics technology; basic engineering principles used in developing therapeutic and diagnostic devices; hands-on labs including optical monitoring, diagnostic and therapeutic experiments.

**Prerequisite:** PHYS 207 or PHYS 208 or approval of instructor; Biomedical Engineering major or minor.

**BMEN 404 FDA Good Laboratory and Clinical Practices****Credits 3. 3 Lecture Hours.**

Implementation of Good Laboratory Practices (GLP) for the submission of preclinical studies and use of Good Clinical Practices (GCP) in clinical trials in accordance with Food and Drug Administration (FDA) regulations; includes similarities and differences in GLP and GCP critical for the introduction of new drugs and medical devices.

**Prerequisites:** BMEN 253; junior or senior classification.

**BMEN 406 Medical Device Path to Market****Credits 3. 3 Lecture Hours.**

Path to market for a medical device with specific attention to the regulatory affairs to enable the development of an appropriate regulatory strategy due to the highly regulated global environment.

**Prerequisites:** BMEN 253; junior or senior classification, or approval of instructor.

**BMEN 420 Medical Imaging****Credits 3. 3 Lecture Hours.**

The principles of the major imaging modalities including x-ray radiography, x-ray computed tomography (CT), ultrasonography and magnetic resonance imaging; including a brief discussion on other emerging imaging technologies such as nuclear imaging (PET and SPECT).

**Prerequisites:** Grade of C or better in BMEN 211; junior or senior classification.

**BMEN 422 Bioelectromagnetism****Credits 3. 3 Lecture Hours.**

Electric, magnetic and electromagnetic phenomena associated with biological tissues; source modeling based on physiological current including line and volume conductor models as well as electromagnetic-based stimulation, sensing and imaging.

**Prerequisites:** Admission into the degree sequence of the major and BMEN 321 or approval of instructor.

**BMEN 425 Biophotonics****Credits 3. 3 Lecture Hours.**

Theory and application of optical instrumentation, including light sources, lasers, detectors, and optical fibers; instrumentation and engineering in biomedical applications of optics in therapeutics, diagnostics, and biosensing.

**Prerequisites:** Admitted into the major degree sequence in biomedical engineering; junior or senior classification.

**BMEN 427 Magnetic Resonance Engineering****Credits 3. 2 Lecture Hours. 3 Lab Hours.**

Design, construction and application of instrumentation for MR imaging; fundamentals of the architecture of an MR spectrometer and the gradient subsystem used for image localization; emphasis on the radiofrequency sensors and systems used for signal generation and reception.

**Prerequisites:** Grade of C or better in ECEN 322 or BMEN 420; junior or senior classification.

**BMEN 428/CSCE 461 Embedded Systems for Medical Applications****Credits 3. 2 Lecture Hours. 3 Lab Hours.**

Principles of embedded system architecture and programming; fundamentals and theoretical foundations of wireless communication systems; hands-on experiences of how an embedded system could be used to solve problems in biomedical engineering; projects on wireless sensors and imaging for medical devices.

**Prerequisite:** BMEN 211, CSCE 350/ECEN 350, or CSCE 315, or approval of instructor.

**Cross Listing:** CSCE 461/BMEN 428.

**BMEN 431 Biomolecular Engineering****Credits 3. 3 Lecture Hours.**

Foundations for understanding and experimental approaches for measuring and manipulating biomolecules; proteins, nucleic acids and carbohydrates; thermodynamics and kinetics of biomolecular reactions.

**Prerequisites:** Junior or senior classification; Biomedical Engineering majors only; or approval of instructor.

**BMEN 432 Molecular and Cellular Biomechanics****Credits 3. 3 Lecture Hours.**

Introduces biomolecules and their assemblies that play structural and dynamical roles in subcellular to cellular level mechanics; emphasis on quantitative/theoretical descriptions; discussions of the relevant experiment approaches to probe these nano to micro-scale phenomena; includes topics in self-assembly of cytoskeleton and biomembranes, molecular motors, cell motility, and mechanotransduction.

**Prerequisite:** BMEN 361.

**BMEN 433 Biomolecular and Cellular Engineering Laboratory****Credits 3. 2 Lecture Hours. 3 Lab Hours.**

Laboratory biosafety and biohazard awareness; cell culture protocols and standards for biocompatibility testing; setting protocols for cellular and biomolecular projects; bioimaging, bioassays and biomolecule activity testing.

**Prerequisites:** VTPP 435; BMEN 431 or concurrent enrollment; majors in biomedical engineering; junior or senior classification; or approval of instructor.

**BMEN 448 Healthcare Technology in the Developing World****Credits 3. 1 Lecture Hour. 6 Lab Hours.**

Principles of operation for major types of medical equipment; physiology underlying the measurement; major functional (system) pieces for each instrument; typical problems/applications of each instrument.

**Prerequisite:** Grade of C or better in MATH 152 and PHYS 207; approval of instructor.

**BMEN 450 Case Studies****Credit 1. 1 Lecture Hour.**

Examination of the process through which clinically defined problems are addressed from the perspective of biomedical engineering through the use of case studies; issues of technology transfer and clinical evaluation.

**Prerequisite:** Admitted to major degree sequence; junior or senior classification.

**BMEN 452 Mass and Energy Transfer in Biosystems****Credits 3. 3 Lecture Hours.**

Transport phenomena associated with physiological systems and their interaction with medical devices; exchange processes in artificial life support systems and diagnostic equipment.

**Prerequisite:** Grade of C or better in BMEN 341; Biomedical Engineering major or minor.

**BMEN 453 Analysis and Design Project I****Credits 2. 6 Lab Hours.**

Group or team biomedical engineering analysis and design project involving statement, alternative approaches for solution, specific system analysis and design.

**Prerequisites:** Grade of C or better in BMEN 321 and BMEN 353.

**BMEN 454 Analysis and Design Project II****Credits 2. 0 Lecture Hours. 6 Lab Hours.**

Continuation of BMEN 453.

**Prerequisite:** Grade of C or better in BMEN 453.

**BMEN 457 Orthopedic Biomechanics****Credits 3. 3 Lecture Hours.**

Development of competencies in biomechanical principles using practical examples and clinical case studies; application of biomechanical knowledge to the evaluation of musculoskeletal tissues and structures, and treatment options for musculoskeletal dysfunction.

**Prerequisite:** BMEN 361 or equivalent course approved by instructor.

**BMEN 458 Motion Biomechanics****Credits 3. 3 Lecture Hours.**

Skeletal anatomy and mechanics; muscle anatomy and mechanics; theory and application of electromyography; motion and force measuring equipment and techniques; inverse dynamics modeling of the human body; current topics in musculoskeletal biomechanics research.

**Prerequisites:** BMEN 207 or approval of instructor; junior or senior classification.

**BMEN 461 Cardiac Mechanics****Credits 3. 3 Lecture Hours.**

Application of continuum mechanics and computational solid mechanics to the study of the mammalian heart; utilization of continuum mechanics and finite element analysis in solving non-linear boundary value problems in biomechanics.

**Prerequisites:** BMEN 341 and BMEN 361.

**BMEN 463 Soft Tissue Mechanics and Finite Element Methods****Credits 3. 3 Lecture Hours.**

Application of continuum mechanics and finite element methods to the study of the mechanical behavior of soft tissues and associative applications in biomedicine.

**Prerequisites:** BMEN 341 and BMEN 361.

**BMEN 465 Biomechanics Experiential Learning Lab****Credit 1. 3 Lab Hours.**

Applications in biomechanics (solid and fluid); includes experimental methods used to investigate biomechanical factors in the assessment of therapeutic interventions; mechanical testing load frames; motion capture systems, high speed imaging and flow systems; hypothesis forming, experimental design, empirical observation, data collection and interpretation, and presentation of results.

**Prerequisite:** Grade of C or better in BMEN 361.

**BMEN 469 Entrepreneurial Pathways in Medical Devices****Credits 3. 3 Lecture Hours.**

Overview of fundamental elements and development steps for an effective strategy pathway including regulatory pathway for commercialization of medical product/medical device innovations; application of the basic regulations and associated requirements and enforcements for product market approval; exploration of product quality test method design requirements; understanding of the applicable regulations and standards pertaining to the design, testing, approval and marketing of medical devices.

**Prerequisite:** Admitted to major degree sequence (upper-level) in biomedical engineering.

**BMEN 471 Numerical Methods in Biomedical Engineering****Credits 3. 3 Lecture Hours.**

Application of numerical analysis to analyze molecular, cellular and physiological systems, using general techniques including programming in MATLAB to analyze steady and dynamic systems.

**Prerequisites:** BMEN 207 and VTPP 434.

**BMEN 480 Biomedical Engineering of Tissues**

**Credits 3. 3 Lecture Hours.**

Introduction to aspects of tissue engineering with and emphasis placed on tissue level topics including tissue organization and biological processes, with insights from recent literature (state-of-the-art).

**Prerequisite:** BMEN 343.

**BMEN 482 Polymeric Biomaterials**

**Credits 3. 3 Lecture Hours.**

Preparation, properties, and biomedical applications of polymers including polymerization; structure-property relationships; molecular weight and measurement; morphology; thermal transitions; network formation; mechanical behavior; polymeric surface modification; polymer biocompatibility and bioadhesion; polymers in medicine, dentistry, and surgery; polymers for drug delivery; polymeric hydrogels; and biodegradable polymers.

**Prerequisite:** BMEN 343.

**BMEN 483 Polymeric Biomaterial Synthesis**

**Credits 3. 3 Lecture Hours.**

Overview of polymer synthetic routes and key structure-property relationships with emphasis on the design of polymeric systems to achieve specific properties; tissue engineering and drug delivery applications will be used as model systems to explore the process of biomaterial design from synthesis to device evaluation.

**Prerequisite:** BMEN 343 or approval of instructor.

**BMEN 484 Internship**

**Credits 0 to 3. 0 to 3 Other Hours.**

Industry experience from both an experiential perspective as well as networking; reflect upon the experience gained during an internship with an outside entity; learn what it takes to be successful in industry.

**Prerequisites:** Admission to Biomedical Engineering major; BMEN 253.

**BMEN 485 Directed Studies**

**Credits 0 to 6. 0 to 6 Other Hours.**

Allows students to undertake special projects in biomedical engineering.

**Prerequisite:** Approval of instructor or Director of Undergraduate Programs.

**BMEN 486 Biomedical Nanotechnology**

**Credits 3. 3 Lecture Hours.**

Nanotechnology applications in biomedicine; concepts of scale; unique properties at the nanoscale; biological interaction, transport, and biocompatibility of nanomaterials; current research and development of nanotechnology for medical applications, including sensors, diagnostic tools, drug delivery systems, therapeutic devices, and interactions of cells and biomolecules with nanostructured surfaces.

**Prerequisite:** BMEN 343, senior classification or approval of instructor.

**BMEN 487 Drug Delivery**

**Credits 3. 3 Lecture Hours.**

Mechanisms for controlled release of pharmaceutically active agents and the development of useful drug delivery systems; controlled release mechanisms including diffusive, convective, and erosive driving forces by using case studies related to oral, topical and parenteral release in a frontier interdisciplinary scientific research format.

**Prerequisites:** BMEN 343; senior classification in biomedical engineering or approval of instructor.

**BMEN 489 Special Topics in...**

**Credits 1 to 4. 1 to 4 Lecture Hours. 1 to 4 Lab Hours.**

New or unique areas of biomedical engineering which are of interest to biomedical engineering and other undergraduate students.

**BMEN 491 Research**

**Credits 0 to 4. 0 to 4 Other Hours.**

Research conducted under the direction of faculty member in biomedical engineering. May be repeated for credit.

**Prerequisites:** Junior or senior classification and approval of instructor.