

# BMEN - BIOMEDICAL ENGINEERING (BMEN)

## 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 201 Professional Development Essentials

**Credits 3. 3 Lecture Hours.** Examination of professional development essentials required to be a professional biomedical engineer; topics include academic, engineering, and medical ethics; critical thinking and problem-solving skills; and written, verbal, and mathematical communication skills. **Prerequisites:** Grade of C or better in MATH 308 or concurrent enrollment; 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, and computer-aided design application in SolidWorks environments. **Prerequisite:** Grade of C or better in MATH 152 and ENGR 102; Biomedical Engineering major.

## 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 250 Biostatistics and Data Visualization

**Credits 3. 3 Lecture Hours.** Introduction to statistical thinking for biomedical engineering problem-solving and decision-making applied to the benchtop, laboratory, and clinical testing and to the quality engineering procedures of verification and validation; topics include descriptive statistics, estimation, hypothesis testing, regression and correlation, experimental design, data visualization, and ethics of statistical practice. **Prerequisites:** Grade of C or better in MATH 152 and ENGR 102; Biomedical Engineering major.

## BMEN 253 Discovering Biomedical Engineering Design Thinking

**Credit 1. 1 Lecture Hour.** Identification and exploration of what constitutes a medical device and the unique aspects of medical device design that are imposed by medical device regulation. **Prerequisite:** Biomedical Engineering major.

## BMEN 254 Biomedical Engineering Design I

**Credit 1. 1 Lecture Hour.** Introduction into biomedical engineering design and relevant biomedical topics. **Prerequisites:** Grade of C or better in BMEN 253; Biomedical Engineering major.

## 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 311 Imaging Living Systems

**Credits 3. 3 Lecture Hours.** Examination of microscopy and clinical imaging modalities in biomedical applications across intracellular to whole body length scales; microscopy topics include optical, electron, scanning probe, infrared, intravital, and other techniques; clinical imaging techniques to be covered include x-ray, ultrasound, magnetic resonance imaging, computed and positron emission tomography, and other specialized clinical imaging. **Prerequisites:** Grade of C or better in BMEN 207 or approval of instructor; Biomedical Engineering major.

## BMEN 321 Circuits, Signals, and Systems

**Credits 3. 2 Lecture Hours. 3 Lab Hours.** Examination of circuits and linear and nonlinear systems concepts required for quantitative analysis of biomedical and physiological signals and design of biomedical systems; topics include electrical circuit fundamentals, operational amplifiers, frequency response, electrical transients, impulse response, transfer functions, convolution, Fourier and Laplace transforms, filtering of biomedical signals, electrical circuits and analog representations of physiological systems as model systems, and A/D conversion and sampling; theoretical investigations and hands-on acquisition of biomedical signals and designing, building, and testing bioinstrumentation circuits. **Prerequisites:** Grade of C or better in BMEN 207, BMEN 250, MATH 308, and PHYS 207; Biomedical Engineering major.

## 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 Biotransport

**Credits 3. 3 Lecture Hours.** Fundamentals of momentum, mass, and energy transport related to living or biomedical systems; examination of the basic principles and constitutive equations of a variety of biological transport phenomena, with length scales ranging from intracellular to organ level; topics include fluid mechanics; transport by diffusion, along with effects of convection, electrochemical potential, and chemical reactions; and energy-tissue interactions; emphases are given to fundamental principles, quantitative approaches, and biomedical applications of these principles and techniques. **Prerequisites:** Grade of C or better in BMEN 207, MATH 308, and PHYS 207 or PHYS 208; Biomedical Engineering major.

## BMEN 343 Biomedical Engineering Materials

**Credits 3. 2 Lecture Hours. 3 Lab Hours.** Properties, preparation, and characterization of natural and man-made materials encountered in biomedical applications; topics include the chemical structure of metals, ceramics, and polymers; physical, mechanical, bulk, and surface properties of biomaterials; biomaterial degradation; and biomaterial processing; theoretical investigations and hands-on acquisition and interpretation of biomaterial preparation and characterization data. **Prerequisites:** Grade of C or better in MATH 308 and BMEN 361; Biomedical Engineering major.

## BMEN 344 Biological Interactions and Testing

**Credits 3. 2 Lecture Hours. 3 Lab Hours.** Application of quantitative engineering principles and bioimaging, bioassay, and biomolecule activity testing to elucidate the interactions between materials and biological systems; topics include protein and cell interactions with biomaterials; biomaterial implantation; acute inflammation, wound healing and the presence of biomaterials immune responses to biomaterials; thrombosis; infection; tumorigenesis; and calcification of biomaterials; examination of theoretical investigations, hands-on acquisition, and interpretation of biological interaction data. **Prerequisite:** Grade of C or better in MATH 308 and VTPP 435; Biomedical Engineering major.

## 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 250.

## BMEN 351 Biomedical and Health Data Science

**Credits 3. 3 Lecture Hours.** Exploration of applications of data analytics, machine learning, and deep learning in health sciences and biomedical data; topics include theoretical foundations, algorithms and methods of deriving valuable insights from data, predictive health analysis, electronic health records, medical image analysis, computational drug discovery, and genome structure prediction using predictive modeling. **Prerequisites:** Grade of C or better in BMEN 207 and BMEN 250; Biomedical Engineering major.

## BMEN 353 Biomedical Engineering Device Design II

**Credit 1. 1 Lecture Hour.** Identification of needs, concept ideation and selection, and creating an initial prototype for user testing within the biomedical engineering process. **Prerequisites:** Grade of C or better in BMEN 254; Biomedical Engineering major.

## BMEN 354 Biomedical Engineering Design III

**Credits 2. 2 Lecture Hours.** Analysis of validation and verification testing for biomedical engineering design, along with manufacturing readiness, market-entry readiness, and post-market engineering activities. **Prerequisites:** Grade of C or better in BMEN 353; Biomedical Engineering major.

## BMEN 361 Biomedical Engineering Mechanics

**Credits 3. 2 Lecture Hours. 3 Lab Hours.** Examination of biomedical engineering mechanics with a focus on biomedical devices, biomaterials, and hard and soft biological tissues; topics include fundamentals of static mechanics, motion biomechanics, and mechanics of materials supplemented with experimental design, simulation, and mechanical testing; exploration of theoretical investigations and hands-on acquisition; interpretation and application of biomechanical data. **Prerequisites:** Grade of C or better in BMEN 207 and BMEN 250; Biomedical Engineering major.

## 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.** Principles of 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 321; 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:** Grade of C or better in BMEN 321, 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:** Grade of C or better in BICH 410; 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 3. 2 Lecture Hours. 3 Lab Hours.** Team-based biomedical engineering analysis and design project involving needs statement generation, ideation, technical specifications, subsystem analysis, and design of complete biomedical system to fit unique needs. **Prerequisites:** Grade of C or better in BMEN 321, BMEN 344, BMEN 354, and BMEN 361; Biomedical Engineering major.

## BMEN 454 Analysis and Design Project II

**Credits 3. 9 Lab Hours.** Continuation of BMEN 453. **Prerequisite:** Grade of C or better in BMEN 453; Biomedical Engineering major.

## 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 481 Seminar

**Credits 0. 0 Other Hours.** Research based seminar focused on the identification and pursuit of research experiences within the local biomedical engineering community. Must be taken on a satisfactory/unsatisfactory basis. **Prerequisites:** BMEN major; junior or senior classification.

## 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; polymetric 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.