BE - BIOMEDICAL ENGINEERING (BE)

BE 100 - Problem Solving in the Biological Sciences & Engineering 4 Credits

Hours: 3R-3L-4C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: None

This course introduces students to computational tools for solving problems in biology and biomedical engineering. The primary thrust of the course is structured programming in MatLab. In addition, we will explore data description, the proper presentation of data, effective use of spreadsheet tools in data analysis, and structured programming.

BE 118 - Design Thinking and Communication 2 Credits

Hours: 1R-3L-2C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: None

Engineers must be able to communicate their design ideas to others. This course focuses on the improvement of communication skills, including written and oral presentation, sketching, and solid modeling. Student groups work on projects with the goal of recognizing and developing behaviors associated with consensus decision-making and cooperative teamwork. Students also learn the steps of the engineering design process and fundamental machining techniques.

BE 118L - Design Communications Lab 0 Credits

Hours: 0R-3L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 121 - DC Circuits 2 Credits

Hours: 1R-3L-2C
Term Available: W
Graduate Studies Eligible: No
Prerequisites: None

This course introduces the fundamentals of DC circuit design and analysis. DC circuit analysis tools such as Kirchhoff's laws, mesh and nodal analysis, superposition, and source transformations are introduced.In conjunction with BE128, students will complete projects that utilize microcontrollers and resistive sensors to interact with their environments.

BE 121L - DC Circuits 0 Credits

Hours: 0R-3L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 122 - Systems Accounting and Modeling I 3 Credits

Hours: 3R-0L-3C
Term Available: W
Graduate Studies Eligible: No
Prerequisites: MA 111 or MA 101 or MA RA100 or MA 105

This course introduces the principles of static equilibrium and their applications in two and three-dimensional engineering systems. Topics covered include vector analysis, free-body diagrams, particle and rigid body equilibrium, and the structural analysis of frames and machines. Fundamental topics related to the elastic behavior of engineering materials under axial loading are introduced. Students may not receive credit towards graduation for both ENGD110 and any of BE 122, EM 120, or EM 121.

BE 128 - Design Thinking & Realization 3 Credits

Hours: 2R-3L-3C
Term Available: W
Graduate Studies Eligible: No
Prerequisites: BE 121 (may be taken concurrently)

This course explores elements of the engineering design process as a means of enhancing students' abilities to define problems, develop and evaluate creative alternatives, and effectively present technical information.

BE 131 - AC Circuits 2 Credits

Hours: 1R-3L-2C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: BE 121 or ENGD 110

This course introduces the fundamentals of AC circuit design and analysis. Topics include RLC circuits, equivalent impedance, phasor domain analysis (nodal analysis, mesh current, source superposition, source transformation), and Thevenin and Norton theorems. The concept of linear systems and the use of electronic components (op-amps, capacitors, inductors) for biosignal processing applications will also be introduced. Students may not receive credit towards graduation for both BE131 and ES213.

BE 131L - AC Circuits Lab 0 Credits

Hours: 0R-0L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 132 - Systems Accounting and Modeling II 3 Credits

Hours: 3R-0L-3C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: BE 122 or EM 120 or EM 121

A common framework for engineering analysis is extended using the concepts of a system, accounting and conservation of extensive properties, constitutive relations, constraints, and modeling assumptions. Stress, strain, and deformation under axial loading are defined. Equilibrium is defined. Conservation equations for mass, charge, momentum and energy are developed. Applications are developed from multiple engineering disciplines. Students may not receive credit towards graduation for both BE132 and ES201.

BE 138 - Design Thinking and Human-Centered Products 3 Credits

Hours: 2R-3L-3C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: BE 131 (may be taken concurrently)

This project-based design course focuses on ensuring that products meet the needs of their users. The course incorporates observational methods, brainstorming, prototyping, user testing, business models, and the social, marketing, and engineering constraints that impinge upon products.

BE 199 - Professional Experience 1 Credit

Hours: 1R-0L-1C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: None

The professional experiences course captures the practical work experiences related to the student's academic discipline. Students are required to submit a formal document of their reflections, which communicates how their employment opportunity reinforced and enhanced their academic studies.

BE 211 - Circuits, Sensors, and Measurements 3 Credits

Hours: 2R-3L-3C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: (BE 131 or (ES 213 and ES 213L) or (ENGD 112 and ENGD 122) or ENGD 120) and (MA 112 or MA 107)

This course introduces the concepts of biomedical signal measurement and conditioning. Topics include amplifiers, filters and A/D converters, digital logic, biomedical sensors and uncertainty analysis. Matlab is used in the context of biosignal acquisition and visualization.

BE 211L - Circuits,Sensors,Meas Lab 0 Credits

Hours: 3R-0L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 218 - Design Methodologies 3 Credits

Hours: 2R-3L-3C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: BE 138

Introduction to the philosophy and goals of various design and research processes. Hands-on projects will serve as vehicles for design thinking, visualization, and methodology.

BE 218L - Design Methodologies Lab 0 Credits

Hours: 0R-3L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 222 - Mechanics of Materials 4 Credits

Hours: 4R-0L-4C
Term Available: W
Graduate Studies Eligible: No
Prerequisites: BE 122 or EM 120 or EM 121 or ENGD 205

Description: Strength and elastic deflection of engineering materials due to loads applied in torsion, in bending, and in shear. Shear diagrams, bending moment diagrams, and area moments of inertia. Combined stresses and principal stresses. Applications to design of beams and shafts. Students may not receive credit towards graduation for both BE 222 and any of EM 203 or EM 204.

BE 228 - Design Leadership & Teamwork 2 Credits

Hours: 1R-3L-2C
Term Available: W
Graduate Studies Eligible: No
Prerequisites: BE 218

This project-based course will help students develop skills in decision-making, leadership, and management of complex design projects.

BE 232 - Biomechanics 3 Credits

Hours: 3R-0L-3C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: BE 222 or EM 203 or EM 204

This course introduces students to the various interdisciplinary fields in biomechanics - such as orthopaedic biomechanics, biofluid mechanics, soft tissue mechanics, and the biomechanics of human movement. Specific topics include: statics/dynamics of the human body, kinematics during activity; the analysis of forces and stresses/strains in biological structures under loading; constitutive models for biological materials (e.g. bone, cartilage, tendon/ligament); and the relationship between structure and function in tissues and organs. Non-majors interested in taking this course should see the instructor.

BE 233 - Biomaterials 3 Credits

Hours: 3R-0L-3C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: None

Structure-property relationships for metallic, polymeric, and ceramic biomaterials. Study of the interactions of these materials with the body and factors affecting the selection and design of materials for medical implants and devices.

BE 238 - Regulatory Affairs & Product Design 4 Credits

Hours: 3R-3L-4C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: None

Students will build a fundamental understanding of how the FDA regulates medical devices in the UnitedStates, with an emphasis on pathways to market. Project is in conjunction with BE232 and BE233.Includes the submission and review process of a student's AIMS for BE majors (peer, career services, faculty, advisory board approval).

BE 310L - Anlys of Physiologcl Sys I Lab 0 Credits

Hours: 0R-3L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 314 - Musculoskeletal Systems Physiology with Applications 4 Credits

Hours: 4R-0L-4C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: BIO 110 and BE 232 and BE 233 and BE 315 (may be taken concurrently)

An analysis of muscle, bone, and soft tissue physiology/mechanics from a quantitative, system-based approach with an emphasis on clinical applications.

BE 315 - Biomedical Engineering Lab I 2 Credits

Hours: 1R-3L-2C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: BE 232 and BE 233 and MA 223 and BE 314 (may be taken concurrently)

This course emphasizes the fundamental concepts in biomechanics and biomaterials with an emphasis on musculoskeletal applications. Hands-on laboratory projects will be assigned which will require the student to use standard testing equipment and basic instrumentation to execute effective test methods.Written communication of experimental results is emphasized. Non-majors interested in taking this course should see the instructor.

BE 318 - Medical Device Research & Design 3 Credits

Hours: 2R-3L-3C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: BE 238 and MA 223

In this course students collaborate with clinicians, industry partners, and/or community partners to identify unmet clinical or research needs. Based on voice of the customer feedback, stakeholder analysis, market analysis, and evaluation of the regulatory and technical landscape, teams will refine observed needs and present them to reviewers. Projects identified to have a significant impact, a committed team, and a viable market can be continued in BE328.

BE 320L - Anlys of Physiological Sys II 0 Credits

Hours: 0R-3L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 321 - Biosignal Processing 4 Credits

Hours: 3R-3L-4C
Term Available: W
Graduate Studies Eligible: No
Prerequisites: (BE 211 or BE 202) and (MA 211 or MA 221) and BE 324 (may be taken concurrently)

This course introduces the fundamentals of biomedical signal processing strategies. Topics include data acquisition, A/D and D/A conversion, FIR and IIR digital filter design, time-frequency analysis, and I/O interfaces. Multichannel data processing and high dimensional data analysis techniques are also introduced. Laboratories provide practical experience on the analysis of electrophysiological data, with special emphasis on neurological signals. Students may not receive credit towards graduation for both BE321 and ECE380 or ECE300.

BE 321L - Biosignal Processing Lab 0 Credits

Hours: 0R-3L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 324 - Neural and Endocrine Systems Physiology with Applications 4 Credits

Hours: 3R-3L-4C
Term Available: W
Graduate Studies Eligible: No
Prerequisites: BIO 110 and BE 211 and BE 314

An analysis of neural and endocrine physiology from a quantitative, systems-based approach.

BE 324L - Neural&Endo SysPhysio Lab 0 Credits

Hours: 0R-3L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 328 - Capstone Design I: Designing Products for the Real World 4 Credits

Hours: 3R-3L-4C
Term Available: W
Graduate Studies Eligible: No
Prerequisites: BE 118 and BE 128 and BE 228 and BE 211 and BE 232 and BE 233 and BE 318

This course begins the capstone design sequence in biomedical engineering. Student teams develop design solutions from a set of client-specified needs, establish specifications, plan the project, schedule and efficiently use resources, examine the ethics and safety in engineering design, and work within explicit (or implicit) constraints, such as social, economic, manufacturing, etc. The course culminates with the presentation of the preliminary proposal for the capstone design project in biomedical engineering.

BE 334 - Cardiovascular, Respiratory, and Renal Systems Physiology with Applications 4 Credits

Hours: 3R-3L-4C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: BIO 110 and BE 314 and BE 315

An analysis of cardiovascular, pulmonary, and renal physiology from a quantitative, systems-based approach with an emphasis on biomedical applications.

BE 334L - Cardio,Resp,&Renal SysPhys Lab 0 Credits

Hours: 0R-0L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 335 - Biomedical Engineering Lab II 2 Credits

Hours: 1R-3L-2C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: BE 315

This course emphasizes experimental design and execution in biomechanics, biomaterials, and fluid mechanics with an emphasis on cardiovascular applications. Laboratory experiences will require the student to use standard testing equipment and basic instrumentation to execute effective test methods.Written communication as well as experimental design and execution is emphasized. Non-majors interested in taking this course should see the instructor.

BE 335L - Biomedical Engineering Lab II 0 Credits

Hours: 0R-0L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 338 - Capstone Design II: Product Design & Prototyping 4 Credits

Hours: 3R-3L-4C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: BE 328

This course is a continuation of BE328. The student teams develop prototype solutions through implementation of the design plan from the previous course. This includes development of a test plan, modifications to the design project as needed, risk assessment, and evaluation of design performance relative to initial specifications. This course culminates in the submission of a functional prototype and updated design history files.

BE 340L - Biomed Signal Proc Lab 0 Credits

Hours: 0R-3L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 350 - Biocontrol Systems 4 Credits

Hours: 4R-0L-4C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: ES 205 or BE 211

Biomedical engineers use science, engineering, and mathematics to understand and solve medical problems. The biomedical engineering program at Rose-Hulman produces engineers with the medical and biological expertise needed to solve health care problems during careers in technical and health-related industries, as well as in government or industrial laboratories.

BE 400 - Consulting Engineering Seminar 2 Credits

Hours: 2R-0L-2C
Graduate Studies Eligible: No
Prerequisites: None

Discusses problems in the field of consulting engineering; includes seminars presented by practicing consulting engineers and a suitable project to practice consulting skills. Cross-listed with CE420, ME420, CHE420, ECE466.

BE 410L - Biomed Engr Design I Lab 0 Credits

Hours: 0R-3L-0C
Graduate Studies Eligible: No
Prerequisites: None

BE 418 - Capstone Design III: Product Verification and Validation 4 Credits

Hours: 3R-3L-4C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: BE 338

This course is a continuation of BE338. The student teams iterate on the initial functional prototype based on client feedback, complete testing of the prototype solutions, and transfer the project results to their client. The course culminates with the submission of a critical design document.

BE 428 - Capstone Design IV: Integrated Product Design & Practice 2 Credits

Hours: 1R-3L-2C
Term Available: W
Graduate Studies Eligible: No
Prerequisites: BE 418

This course is a continuation of BE418. Student teams finalize design prototypes, reflect on future product development opportunities, and complete documentation requirements to established standards and specifications. Students participate in a mentorship program with students enrolled in BE328 and begin development of a professional design portfolio.

BE 435 - Biomedical Optics 4 Credits

Hours: 3.5R-1.5L-4C
Term Available: F
Graduate Studies Eligible: Yes
Prerequisites: PH 113 (may be taken concurrently) and (MA 221 or MA 212)

Optical techniques for biomedical applications and health care; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy, biophotonics laboratories. For graduate credit, students must do additional project work on a topic selected by the instructor. Cross-listed with OE 435.

BE 438 - Engineering Portfolio Development 2 Credits

Hours: 1R-3L-2C
Term Available: S
Graduate Studies Eligible: No
Prerequisites: BE 428

Students complete a portfolio showcasing their engineering design work to further a specific professional goal. Examples of professional goals include developing a career plan, pursuing patent opportunities, or establishing a business plan for a start-up. Students participate in a mentorship program with students enrolled in BE338.

BE 482 - Biostatistics 4 Credits

Hours: 4R-0L-4C
Term Available: F
Graduate Studies Eligible: Yes
Prerequisites: MA 223 or MA 382

Hypothesis testing and confidence intervals for two means, two proportions, and two variances. Introduction to analysis of variance to include one factor and two factors (with interaction) designs. Presentation of simple linear and multiple linear regression modeling; development of analysis of contingency table to include logistic regression. Presentation of Log odds ratio as well as several non-parametric techniques of hypothesis testing and construction of non-parametric confidence intervals and correlation coefficients. Review of fundamental prerequisite statistics will be included as necessary.

BE 491 - Special Topics in Biomedical Engineering 1-4 Credits

Hours: 0R-0L-(1 - 4)C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: None

Covers upper-level, undergraduate material of mutual interest to student and instructor which cannot be acquired in any other listed undergraduate BE course.

BE 492 - Directed Study in Biomedical Engineering 1-4 Credits

Hours: 0R-0L-(1 - 4)C
Term Available: F
Graduate Studies Eligible: No
Prerequisites: None

Covers biomedical engineering material of mutual interest to the student and instructor which cannot be experienced in any other listed BE course. A student may take between 1-4 credits in any given term.

BE 499 - Thesis Research 2 Credits

Hours: 0R-6L-2C
Term Available: F,W,S
Graduate Studies Eligible: No
Prerequisites: None

Culmination of biomedical engineering thesis research in which a student writes and submits the senior thesis, following departmentally established guidelines, and gives an oral research presentation to at least three departmental faculty members, including the student's adviser. BE499 may not be used as a biomedical engineering area elective.

BE 515 - Mechanobiology 4 Credits

Hours: 4R-0L-4C
Term Available: S
Graduate Studies Eligible: Yes
Prerequisites: BE 232

This course will discuss the role physical forces play on biological processes and how mechanical stimuli can be utilized to improve tissue engineering, regenerative medicine, and rehabilitation strategies.

BE 516 - Introduction to MEMS: Fabrication & Applications 4 Credits

Hours: 3R-3L-4C
Term Available: S
Graduate Studies Eligible: Yes
Prerequisites: None

Properties of silicon wafers, wafer-level processes, surface and bulk micromachining, thin-film deposition, dry and wet etching, photolithography, process integration, simple actuators. Introduction to microfluidic systems. MEMS application: capacitive accelerometer, cantilever and pressure sensor. Students enrolled in BE516 must do project work on a topic selected by the instructor. Cross-listed with CHE 505, ECE 516, NE 510, and ME 516.

BE 520 - Introduction to Brain Machine Interfaces 4 Credits

Hours: 3R-3L-4C
Term Available: S
Graduate Studies Eligible: Yes
Prerequisites: BE 321 or ECE 380

This course is an introduction to the basics of motor cortical functions related to voluntary and imagery movements, evoked response potentials, invasive vs. noninvasive electrode design considerations, quantitative EEG analysis techniques used in clinical settings, and the applications of brain-machine interfaces/brain-computer interfaces in the restoration of mobility, communication and motor function.

BE 535 - Biomedical Optics 4 Credits

Hours: 4R-0L-4C
Term Available: W
Graduate Studies Eligible: Yes
Prerequisites: PH 113 and (MA 221 or MA 212)

Optical techniques for biomedical applications and health care; imaging modalities; laser fundamentals, laser interaction with biological cells, organelles and nanostructures; laser diagnostics and therapy, laser surgery; microscopes; optics-based clinical applications; imaging and spectroscopy; biophotonics. Students must do additional project work on a topic selected by the instructor. Students may not receive credit for both OE 435 and OE 535. Cross-listed with OE 535.

BE 541 - Medical Imaging Systems 4 Credits

Hours: 4R-0L-4C
Term Available: W
Graduate Studies Eligible: Yes
Prerequisites: BE 321 or ECE 300 or OE 392

Engineering principles of major imaging techniques/modalities for biomedical applications and health care including diagnostic x-ray, computed tomography, nuclear techniques, ultrasound, and magnetic resonance imaging. Topics include general characteristics of medical images; physical principles, signal processing to generate an image, and instrumentation of imaging modalities. Clinical applications of these technologies are also discussed.Cross-listed with ECE584 and OE584.

BE 543 - Neuroprosthetics 4 Credits

Hours: 3R-3L-4C
Term Available: F,W,S
Graduate Studies Eligible: Yes
Prerequisites: BE 324 and BE 211

This course takes a detailed look at the state of the art in Neuroprosthetics design and applications. Topics include electrode design, sensory prosthetics, functional electrical stimulation, deep brain stimulation and other contemporary research topics.

BE 545 - Orthopaedic Biomechanics 4 Credits

Hours: 4R-0L-4C
Term Available: W
Graduate Studies Eligible: Yes
Prerequisites: EM 203 or EM 204 and BE 222 and BE 232

This course covers current topics in orthopaedic biomechanics including the application of solid mechanics principles to musculoskeletal activities, orthopaedic implants, and fracture fixation devices. Topics include joint loading; composition and mechanical behavior of orthopaedic tissues; design/analysis of artificial joints and fracture fixation prostheses; osteoporosis and osteoarthritis; and finite element modeling.

BE 550 - Research Methods in Biomechanics 4 Credits

Hours: 3R-3L-4C
Term Available: W
Graduate Studies Eligible: Yes
Prerequisites: BE 330 or (BE 331 or BE 232)

Focuses on the wide range of research methods used in the field of biomechanics. Current literature will be reviewed to analyze the advantages and disadvantages of various research methodologies. Topics will vary based on student interests and background, but may include topics such as motion/force analysis, soft tissue and bone mechanics, joint biomechanics, analysis of joint replacements, and fracture fixation. Laboratory activities will reinforce the lecture topics and students will have the opportunity to investigate a biomechanics research topic in their area of interest.

BE 560 - Tissue-Biomaterial Interactions 4 Credits

Hours: 4R-0L-4C
Term Available: W
Graduate Studies Eligible: Yes
Prerequisites: BE 233

Addresses interactions between living cells/tissues and implant biomaterials, stressing the importance of molecular- and cellular-level phenomena in initiating and propagating clinically relevant tissue- and systemic- level results.

BE 570 - Introduction to Tissue Engineering 4 Credits

Hours: 4R-0L-4C
Term Available: W
Graduate Studies Eligible: Yes
Prerequisites: BIO 110 and (BE 233 or CHE 315 or ME 328)

This course provides a broad overview of the latest developments in the field of tissue engineering. Normal structure and function of tissues and organs such as bone, cartilage, nerve, skin, and liver are discussed. Methods of engineering these tissues, or encouraging healing or regeneration that would not otherwise occur, is the focus of the course. The course takes the format of a graduate seminar, with students taking an active role in presenting material to the class and leading discussions.

BE 590 - Thesis Research 0-12 Credits

Hours: 0R-0L-(0 - 12)C
Term Available: F,W,S
Graduate Studies Eligible: Yes
Prerequisites: None

Credits as assigned: however, not more than 12 credits will be applied toward the requirements of an M.S. degree.

BE 597 - Selected Topics for Graduate Students 0-4 Credits

Hours: (0 - 4)R-0L-(0 - 4)C
Term Available: F,W,S
Graduate Studies Eligible: Yes
Prerequisites: None

Selected Topics for Graduate Students Credits as assigned. Maximum 4 credits per term.