

BIOMEDICAL ENGINEERING

Biomedical Engineering

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The Biomedical Engineering program applies engineering principles to biological and medical problems, with the goal of improving human health and understanding fundamental clinical problems. The BS in BME includes cross-disciplinary course work in engineering and life sciences, as well as application-based courses that are focused on analyzing, modeling, designing, and realizing biomedical devices, systems, components, or processes. The program is also dedicated to developing innovative and translational biomedical technologies by combining traditional biomedical training with Artificial Intelligence (AI) approaches while maintaining close relationship with industries to keep the program attractive to the job market.

Program Educational Objectives

The program educational objectives of the BS in Biomedical Engineering program are to produce graduates who, within a few years of graduation:

1. Apply their engineering and problem-solving skills towards engineering practice, engineering graduate school, or other fields such as medicine, science, business, or law.
2. Value and demonstrate character by acting responsibly, ethically, and professionally.
3. Work synergistically in diverse and global environments to positively impact society.
4. Embrace life-long learning to support professional development and personal wellness.

Program Learning Outcomes

Biomedical Engineering Major

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- Communicate effectively with a range of audiences
- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- Develop and conduct appropriate experimentation, analyze, and interpret data, and use engineering judgment to draw conclusions
- Acquire and apply new knowledge as needed, using appropriate learning strategies
- Apply principles of engineering, biology, human physiology, chemistry, calculus-based physics, mathematics (through differential equations) and statistics;
- Solve bio/biomedical engineering problems, including those associated with the interaction between living and non-living systems
- Analyze, modeling, designing, and realizing bio/biomedical engineering devices, systems, components, or processes; and
- Make measurements on and interpreting data from living systems.

The BS in BME curriculum includes cross-disciplinary course work in engineering and life sciences, as well as application-based courses that are focused on analyzing, modeling, designing, and realizing biomedical devices, systems, components, or processes. It includes a pre-med component which provides engineering perspective as an alternative to biology-focused pre-med programs. The program is designed with flexibility in combining a selection of minors, viz., Mechanical Engineering (ME), Electrical Engineering (EE), Computer Engineering (CpE), Computer Science (CS), and Business. Students interested in adding a minor should work with their advisors to plan this coursework.

Bachelor of Science in Biomedical Engineering (BSBME)

(186 credits required for the degree (<http://bulletin.du.edu/undergraduate/undergraduateprograms/traditionalbachelorsprogram/bachelorofscienceinbiomedicalengineering/>))

Code	Title	Credits
Required Engineering Core		
ENGR 1611	Introduction to Engineering Design	4

ENGR 1622	Introduction to Mechatronic Systems I	4
ENGR 1632	Introduction to Mechatronic Systems II	4
COMP 1451	Engineering Programming	4
ENEE 2012	Circuits I and Laboratory	4
ENME 2510	Statics	4
ENME 2710	Engineering Thermodynamics I	3
or ENME 2651	Fluid Dynamics I	
ENGR 3313	Engineering Design Project I	2
ENGR 3323	Engineering Design Project II	3
ENGR 3333	Engineering Design Project III	3
ENGR 1201	Career Readiness I	1
ENGR 2201	Career Readiness II	1
ENGR 3201	Career Readiness III	1
ENGR 3202	Career Readiness IV	1
Biomedical Engineering core		
ENBI 2200 -1	Introduction to Biomechanics	4
ENBI 2400	Introduction to Biomaterials	4
BIOL 2090	Biostatistics	4
ENBI 3150	Bioinstrumentation	4
ENBI 3300	Biotransport	4
ENBI 3200	Cell Mechanics and Mechanotransduction	4
ENBI 3700	Introduction to Regulatory Affairs	4
ENBI 3801	Biomedical Engineering Laboratory	4
Total Hours ¹		68 - 71

¹ Students pursuing the Pre-Med track will have an Engineering Core course waived.

Code	Title	Credits
Additional Requirements		
BIOL 1010	Physiological Systems	4
BIOL 1020	Physiological Systems Lab	1
BIOL 1011	Evolution, Heredity and Biodiversity	4
BIOL 1021	Evolution, Heredity and Biodiversity Lab	1
BIOL 2120	Cell Structure and Function	4
BIOL 2121	Cell Structure & Function Lab	1
BIOL 3241	Anatomy and Physiology of the Skeletal, Nervous and Muscular systems	0-5
BIOL 3242	Human Anatomy and Physiology - Systems of homeostasis	0-5
CHEM 1010	General Chemistry I	3
CHEM 1020	General Chemistry II	3
CHEM 1240	General Chemistry I Laboratory	1
CHEM 1250	General Chemistry II Laboratory	1
MATH 1951	Calculus I	4
MATH 1952	Calculus II	4
MATH 1953	Calculus III	4
MATH 2070	Introduction to Differential Equations	0-4
MATH 2080	Calculus of Several Variables	4
PHYS 1211	University Physics I	5
PHYS 1212	University Physics II	5
PHYS 1214	University Physics III for Engineers	4

Electives

Engineering Electives - 8 credits of 3000 or higher engineering courses (ENGR, ENME, ENEE, ENCE, ENBI), which are not required for the major.

Science or Engineering Electives - 8 credits of 2000 level or higher science (BIOL, CHEM, HLTH, PHYS) or engineering courses (ENGR, ENME, ENEE, ENCE, ENBI)

Pre-Med Track

Students who would like to pursue the BSBME as a pre-health curriculum, should also take the additional courses below. They can also waive the ENME 2710/ENME 2651 requirement with permission of their advisor. Students interested in this pathway should meet with their advisor early to plan.

Code	Title	Credits
CHEM 2131	Chemistry of the Elements	3
CHEM 2141	Chemistry of the Elements Lab	1
CHEM 2451	Organic Chemistry I	3
CHEM 2461	Organic Chemistry Lab I	1
CHEM 2452	Organic Chemistry II	3
CHEM 2462	Organic Chemistry Lab II	1
CHEM 2453	Organic Chemistry III	3
CHEM 2463	Organic Chemistry Lab III	1
CHEM 3811	Biochemistry-Proteins	3
CHEM 3812	Biochemistry-Membranes/Metabolism	3
BIOL 2510	General Genetics	4
BIOL 2511	General Genetics Lab	1
PSYC 1001	Foundations of Psychological Science	4
Total Credits		31

ENBI 2200 Introduction to Biomechanics (4 Credits)

This course introduces the fundamental principles of engineering solid mechanics, including statics, dynamics, and mechanics of materials. The concepts will be applied to solve fundamental problems in biomechanics, including the analysis of human movement and tissue mechanics. Prerequisites: PHYS 1211 and PHYS 1212 and COMP 1451.

ENBI 2400 Introduction to Biomaterials (4 Credits)

Biomaterials is a multidisciplinary field requiring knowledge of biology, chemistry, materials science, mechanics, transport and medicine. In this course we will examine aspects of chemistry, biology, material science and mechanics as they apply to the interaction of a material with a biological system. Our examination of the field will lead to a general understanding of biocompatibility and how to design experiments that assess biocompatibility. PREREQ: ENME 2510 and BIOL 1010.

ENBI 3010 Introduction to Biomedical Engineering (4 Credits)

An introduction to biomedical engineering, this course will serve as a survey of the field of study. During the course students will learn to identify a breadth of biomedical engineering problems and also learn about the technical challenges and opportunities that biomedical engineering brings to the life and medical sciences. Topics may include biomechanics, tissue engineering, medical imaging, bioinstrumentation, and medical device design.

ENBI 3150 Bioinstrumentation (4 Credits)

This course introduces the theory and practice of bioinstrumentation. Students study how biomedical devices acquire, condition, and interpret signals from the human body, with emphasis on biopotential, mechanical, and optical measurements. Topics include sensors and transducers, front-end amplifiers, filtering, digitization, and safety considerations in clinical and research settings. PREREQ: ENEE 2012.

ENBI 3200 Cell Mechanics and Mechanotransduction (4 Credits)

This course explores how mechanical forces regulate cellular behavior, integrating engineering mechanics with molecular and cell biology. Students will examine how cells sense, transmit, and respond to mechanical cues through the cytoskeleton, mechanics of the extracellular matrix, cell-matrix mechanical interactions and mechanosensitive signaling pathways. Topics include cellular viscoelasticity, plasticity, traction force generation, mechanotransduction in health and disease, and emerging technologies for quantifying cell mechanics. Laboratory and computational activities emphasize quantitative data analysis and modeling at the single-cell and multicellular scales. Pre-requisites: ENBI 2200 and ENBI 2400 and BIOL 2120 and BIOL 2121.

ENBI 3300 Biotransport (4 Credits)

This course introduces the fundamental principles of momentum, heat, and mass transport in biological and biomedical systems. Students learn how to formulate and solve biotransport problems at macroscopic, shell-balance, and microscopic scales. Applications include cardiovascular flows, thermal therapies, oxygen transport, tissue engineering, and medical devices. PREREQS: MATH 2070, MATH 2080.

ENBI 3510 Biomechanics (4 Credits)

An introduction to the mechanical behavior of biological tissues and systems. Specific topics covered include analysis of the human musculoskeletal system as sensors, levers, and actuators; joint articulations and their mechanical equivalents; kinematic and kinetic analysis of human motion; introduction to modeling human body segments and active muscle loading for analysis of dynamic activities; mechanical properties of hard and soft tissues; mechanical and biological consideration for repair and replacement of soft and hard tissue and joints; orthopedic implants. Cross listed with ENBI 4510. Prerequisites: ENME 2410, ENME 2520, and ENME 2541.

ENBI 3700 Introduction to Regulatory Affairs (4 Credits)

Biomedical engineers are uniquely involved in many aspects of product development, from the inception of the idea to its delivery in the marketplace. This course will cover one major aspect of that process—the objectives and mechanisms of regulatory systems governing the clinical use of medical devices, including regulatory pathways and device classifications. Students will both analyze and discuss the management of risk, and they will design controls related to cardiovascular, orthopedic, and neurological devices. By the end of the course, students will have a deep understanding of how the regulatory process is involved in every phase of medical device development.

ENBI 3800 Topics in Bioengineering (1-4 Credits)

Special topics in bioengineering as announced. May be taken more than once. Prerequisite: varies with offering.

ENBI 3801 Biomedical Engineering Laboratory (4 Credits)

This course provides a comprehensive, hands-on introduction to experimental methods in biomedical engineering, uniting a diverse range of laboratory experiences across signal processing, biomechanics, biomaterials, and physiological systems. Students will design, conduct, and analyze experiments that integrate engineering theory with biological function, developing technical competence, critical thinking, and data analysis skills essential for modern biomedical research and practice. The course emphasizes advanced learning through experiential problem-solving, including challenges inspired by research and industry applications. Students will strengthen their ability to read scientific literature, analyze real-world data, and compose technical reports and research-style manuscripts, forming an essential foundation for professional and academic success in biomedical engineering. PREREQS: ENBI 2200, ENBI 2400, ENBI 3100, and ENBI 3300.

ENGR 1201 Career Readiness I (1 Credit)

This course establishes the foundational competencies necessary for career literacy, focusing on self-awareness, goal setting, and understanding the core mindset and habits required for success in engineering education and professional growth.

ENGR 1511 Engineering Connections (1 Credit)

This course is designed to help engineering students bridge the gap from high school to a college environment in a very challenging major. Topics and activities may include academic success strategies; interviewing engineering alumni; the ethics of the profession; visits to industry sites; seminars by industry and academic experts; establishing the relationships between math, science, and engineering courses with design projects; critical and creative thinking activities; tours of the research labs of the engineering professors; disseminating information on the dual degree programs, the MBA programs, the honor code, and engineering program structures; and readings from and discussions about articles from professional publications. Membership in an engineering professional society is encouraged.

ENGR 1572 Applied MATLAB Programming (3 Credits)

The MATLAB programming environment is used to introduce engineering applications programming. It includes high performance numerical computation and visualization. Programming topics include an overview of an interactive programming environment, generation of m-files, variables and data types, arithmetic operators, mathematical functions, symbolic mathematics, graphic generation, use of programs in application specific toolboxes, embedding and calling C programs in m-files, file input/output, and commenting. Programming is oriented toward engineering problem solving. Prerequisites: COMP 1571 or COMP 1671 or COMP 1351, and MATH 1952.

ENGR 1611 Introduction to Engineering Design (4 Credits)

Introduction to concepts and practice in computer, electrical and mechanical engineering including engineering ethics. Engineering problem-solving as it applies to engineering analysis, synthesis and design. Students practice structured teamwork and program management skills in the context of projects. Emphasis on computer tools with immediate application to engineering practice.

ENGR 1622 Introduction to Mechatronic Systems I (4 Credits)

Introduction to elementary concepts and practices in mechatronic systems engineering, in particular electrical engineering concepts including current and voltage and basic electrical circuit analysis, interfacing electrical circuits with mechanical systems, and assembly and testing of mechatronics subsystems. Students are required to complete simple projects including mechanical and electrical components during which they practice teamwork while gaining skills in electrical and mechatronic systems troubleshooting. Introduction to Multiscan circuit analysis software and Mathcad are among other topics covered in this course.

ENGR 1632 Introduction to Mechatronic Systems II (4 Credits)

Study of fundamentals of computer-based systems and electromechanical systems controlled by microprocessors or microcontrollers. Introduction to digital logic and electronics. Introduction to LabView and use of LabView to build and evaluate circuits and simple electromechanical systems. Use of logic circuits to build analog to digital converters. Program microcontrollers. Study of autonomous vehicles as mechatronic systems and the ability to control them (small cars, robots, helicopters, quadrotors, etc.). Course requirements include a report with detailed analysis of the vehicle control system, flow charts, and program documentation.

ENGR 1700 Machine Shop Practice (1 Credit)

Introduction to concepts and practice in basic machine tool work (i.e. mill, lathe, welding etc.). The course provides the necessary information for majors and non-majors to gain access to the DU Engineering Machine Shop. Class size is limited to 5 students per quarter. Enrollment priority will be given to engineering majors.

ENGR 1911 Introduction to CAD (2 Credits)

This course is intended for transfer students who have had an introduction to engineering, but who need to learn certain techniques and software typically dealt with in ENGR 1611 including engineering ethics. Instructor Permission Required.

ENGR 1921 Introduction in Engineering II (1 Credit)

This course is intended mainly for transfer students who have had an introduction to engineering with topics similar to those in ENGR 1622, Introduction to Mechatronic Systems I, but who need to learn certain techniques and software (Mathcad and Multisim) typically dealt with in ENGR 1622. Prerequisite: Permission of the instructor.

ENGR 1931 Introduction to Engineering III (1 Credit)

This course is intended mainly for transfer students who have had an introduction to engineering with topics similar to those in ENGR 1632, Introduction to Mechatronic Systems II, but who need to learn certain techniques and software (LabView) typically dealt with in ENGR 1632. Prerequisite: Permission of the instructor.

ENGR 2201 Career Readiness II (1 Credit)

This second course in the Career Readiness sequence builds students' interpersonal and professional skills with a focus on teamwork, communication, emotional intelligence, mentoring relationships, and internship preparation. Through applied activities, practice-based workshops, and real-world scenarios, students strengthen the competencies that help them succeed in diverse teams and professional environments. PREREQ: ENGR 1201 or permission of instructor.

ENGR 2610 Engineering Integration I (3 Credits)

Interdisciplinary course combining topics from computer, electrical and mechanical engineering including engineering ethics, with emphasis on laboratory experience and the design, analysis and testing of interdisciplinary systems. Manufacture of mechanical systems and/or circuit boards. Team project work on interdisciplinary "design-and-build" projects. Prerequisites: Junior standing in the appropriate engineering discipline and ENME 3511 for MME majors or ENCE 3210 and ENEE 2211 for ECE majors (the latter three can be taken concurrently).

ENGR 2620 Engineering Integration II (3 Credits)

Interdisciplinary course combining topics from computer, electrical and mechanical engineering including engineering ethics, with emphasis on laboratory experience and the design, analysis and testing of interdisciplinary systems. Manufacture of mechanical systems and/or circuit boards. Team project work on interdisciplinary "design-and-build" projects. Prerequisite: ENGR 2610.

ENGR 2905 Engineering Cooperative Education (0-12 Credits)

For students on full-time cooperative educational employment. This course may be taken up to four times. Any and all credits will not count toward your degree and you will receive a grade of NC (no credit) for all enrollments. You will choose between a residential and non-residential section.

ENGR 2910 Engineering Economics and Ethics (3 Credits)

This course focuses on the practical applications of economics to engineering focusing on the requirements for both the FE and PE exams. It explains concepts in accounting and finance and applies them to both engineering and personal situations. Topics that are discussed include: economic decision making, interest, inflation, depreciation, income taxes, and rate of return. In addition, the engineer's role in society, including global, economic, environmental, societal, and ethical issues will be discussed.

ENGR 2950 Engineering Assessment I (0 Credits)

Examination covering basic mathematics, science and sophomore-level engineering topics. Co-Requisite: MATH 2080; Prerequisite: ENME 2541 AND ENCE 2101 AND ENEE 2012 AND ENGR 1572.

ENGR 2951 Engineering Assessment II (0 Credits)

Students perform a lifelong learning experience and assessment-related tasks, e.g. a survey and exit interview. The course also includes career and professional development, as well as information on the Fundamentals of Engineering (FE) exam. Engineering students are encouraged, but not required to complete the FE exam. This course should be taken in the last year of attendance. Prerequisites: ENGR 3323.

ENGR 3100 Instrumentation and Data Acquisition (4 Credits)

This course examines different instrumentation techniques and describes how different measurement instruments work. Measurement devices include length, speed, acceleration, force, torque, pressure, sound, flow, temperature, and advanced systems. This course also examines the acquisition, processing, transmission and manipulation of data. Cross listed with ENGR 4100. Prerequisites: PHYS 1213 or PHYS 1214.

ENGR 3201 Career Readiness III (1 Credit)

ENGR 3201 Career Readiness III prepares students to navigate the complexities of professional environments by strengthening critical thinking, professionalism, ethical decision-making, and responsible use of emerging technologies—including AI. Students will engage with real, ambiguous workplace scenarios, analyze ethical dilemmas, practice intermediate interview skills, and learn to apply professional norms that enhance credibility and effectiveness. This course emphasizes problem-solving, professional judgment, and strategic communication to help students stand out in competitive internship and job markets. PREREQ: ENGR 2201.

ENGR 3202 Career Readiness IV (1 Credit)

ENGR 3202 Career Readiness IV is the culminating experience in the career readiness sequence. This course prepares graduating seniors to enter the professional world with confidence by deepening their leadership capacities, strengthening self-reflection skills, and enhancing their ability to navigate organizational culture, networking, interviewing, and career transitions. Students will analyze workplace norms, practice advanced interpersonal and communication skills, and learn strategies for evaluating job offers, negotiating effectively, and managing early-career growth. The overarching goal is to help students become thoughtful, values-aligned professionals and strong contributors in their first post-college roles. PREREQ: ENGR 3201.

ENGR 3313 Engineering Design Project I (2 Credits)

Planning, development and execution of an engineering design project. The project may be interdisciplinary, involving aspects of computer, electrical and mechanical engineering. Projects have economic, ethical, social and other constraints, as appropriate. Design activities include 1) preparation and presentation of proposals in response to requests-for-proposals from "customers," including problem description, quantitative and qualitative criteria for success, alternate designs and project plans; 2) generation and analysis of alternate designs, and choice of best design; 3) formulation of test procedures to demonstrate that the design chosen meets the criteria for success, and testing of the completed project where feasible; 4) reporting on the design and testing. Prerequisite: ENGR 2620 and ((ENME 3511 and ENME 2671) or (ENCE 3231)) and senior standing in engineering.

ENGR 3323 Engineering Design Project II (3 Credits)

Planning, development and execution of an engineering design project. The project may be interdisciplinary, involving aspects of computer, electrical and mechanical engineering. Projects have economic, ethical, social and other constraints, as appropriate. Design activities include 1) preparation and presentation of proposals in response to requests-for-proposals from "customers," including problem description, quantitative and qualitative criteria for success, alternate designs and project plans; 2) generation and analysis of alternate designs, and choice of best design; 3) formulation of test procedures to demonstrate that the design chosen meets the criteria for success, and testing of the completed project where feasible; 4) reporting on the design and testing. Prerequisite ENGR 3313.

ENGR 3333 Engineering Design Project III (3 Credits)

Planning, development and execution of an engineering design project. The project may be interdisciplinary, involving aspects of computer, electrical and mechanical engineering. Projects have economic, ethical, social and other constraints, as appropriate. Design activities include: 1) preparation and presentation of proposals in response to requests-for-proposals from "customers," including problem description, quantitative and qualitative criteria for success, alternate designs and project plans; 2) generation and analysis of alternate designs, and choice of best design; 3) formulation of test procedures to demonstrate that the design chosen meets the criteria for success, and testing of the completed project where feasible; 4) reporting on the design and testing. Prerequisite ENGR 3323.

ENGR 3340 Product Development and Market Feasibility (4 Credits)

In this course, students gain knowledge of designing products for market success by developing a product and optimizing its design for specific mass manufacturing technologies. Students gain experience through the design development process including market feasibility research, human-centered design, brainstorming and ideating new concepts, refinement through design iteration, and constructing alpha and beta prototypes that are designed with mass manufacturing considerations. Projects are based upon real world new product development principles. Students learn and practice the fundamentals of design thinking, design process, and entrepreneurship.

ENGR 3450 Biosensing Technology (4 Credits)

Biosensors are defined as analytical devices incorporating a biological material, a biologically derived material or a biomimic associated with or integrated within a physicochemical transducer or transducing microsystem, which may be optical, electrochemical, thermometric, piezoelectric, magnetic or micromechanical. This course provides instruction in the basic science and engineering concepts required to understand the design and application of biosensors. This module serves as an introduction to some of the biosensors and measurement techniques.

ENGR 3455 Fluorescence and Its Applications in Biomedical Sensors (4 Credits)

The course introduces the principles of fluorescence and its applications in the real world. It covers various topics including fluorophores (dye, fluorescent proteins, quantum dots, etc.), nanomaterials and nanostructures, design of biomedical sensors, point-of-care systems, and wearable devices. Cross listed with ENGR 4455.

ENGR 3510 Renewable and Efficient Power and Energy Systems (4 Credits)

This course introduces the current and future sustainable electrical power systems. Fundamentals of renewable energy sources and storage systems are discussed. Interfaces of the new sources to the utility grid are covered. Prerequisite: ENEE 2012.

ENGR 3520 Introduction to Power Electronics (4 Credits)

This covers fundamentals of power electronics. We discuss various switching converters topologies. Basic knowledge of Efficiency and small-signal modeling for the DC-DC switching converters is covered. Furthermore, magnetic and filter design are introduced. Prerequisites: ENEE 2211 and ENGR 3722.

ENGR 3530 Introduction to Power and Energy Conversion Systems (3 Credits)

Basic concepts of AC systems, single-phase and three-phase networks, electric power generation, transformers, transmission lines, and electric machinery. Cross listed with ENGR 4530. Prerequisite: ENEE 2022.

ENGR 3535 Electric Power Engineering Laboratory (1 Credit)

In this laboratory, the magnetic circuits, single phase transformers, power quality and harmonics synchronous machines, Induction machines and DC machines are studied and tested in a real physical setup. Prerequisite: ENGR 3530.

ENGR 3540 Electric Power Systems (4 Credits)

This course covers methods of calculation of a comprehensive idea on the various aspects of power system problems and algorithms for solving these problems. Prerequisite: ENGR 3530.

ENGR 3545 Electric Power Economy (3 Credits)

This course covers economy aspects of electric power industry and the implications for power and energy engineering in the market environment. Cross listed with ENGR 4545. Prerequisite: ENGR 3530.

ENGR 3590 Power System Protection (3 Credits)

This course covers methods of calculation of fault currents under different types of faults; circuit breakers, current transformers, potential transformers; basic principles of various types of relays; applications of relays in the protection of generator, transformer, line, and bus, etc. Prerequisite: ENEE 2022, ENGR 3530 or equivalent. 3.0 hours. Cross listed with ENGR 4590.

ENGR 3611 Engineering Mathematics (3 Credits)

Applied mathematics for engineers. Generalized Fourier analysis, complex variables, vector calculus, introduction to partial differential equations, and linear algebra. Prerequisites: MATH 2070, MATH 2080.

ENGR 3621 Advanced Engineering Mathematics (4 Credits)

Applied mathematics for engineers. Topics include vector spaces, normed vector spaces, inner product spaces, linear transformations, finite-dimensional linear transformations, linear operators, finite-dimensional linear operators, linear differential systems, linear difference systems, orthogonal transformations, amplitude estimation, fundamentals of real and functional analysis, and introduction to partial differential equations, and applications to engineering systems.

ENGR 3630 Finite Element Methods (4 Credits)

Introduction to the use of finite element methods in one or two dimensions with applications to solid and fluid mechanics, heat transfer and electromagnetic fields; projects in one or more of the above areas. Prerequisites: ENME 2541 AND ENGR 1572.

ENGR 3650 Probability and Statistics for Engineers (4 Credits)

This course covers quantitative analysis of uncertainty and decision analysis in engineering. It covers the fundamentals of sample space, probability, random variables (discrete and continuous), joint and marginal distributions, random sampling and point estimation of parameters. It also covers statistical intervals, hypotheses testing and simple linear regression. The course includes applications appropriate to the discipline. Prerequisite: MATH 1953.

ENGR 3721 Controls (3,4 Credits)

Modeling, analysis and design of linear feedback control systems using Laplace transform methods. Techniques and methods used in linear mathematical models of mechanical, electrical, thermal and fluid systems are covered. Feedback control system models, design methods and performance criteria in both time and frequency domains. A linear feedback control system design project is required. Prerequisites: ENEE 2022, ENGR 3611 or permission of instructor.

ENGR 3722 Control Systems Laboratory (1 Credit)

This laboratory course serves as supplement to ENGR 3721. It aims at providing "hands on" experience to students. It includes experiments on inverted pendulum, gyroscopes, motor control, feedback controller design, time-domain and frequency domain. Corequisite: ENGR 3721.

ENGR 3723 Digital Control (4 Credits)

The course focuses on modeling, analysis, and design of digital control systems. Topics include: z-Transform and difference equations; sampling and aliasing; Zero-Order Hold (ZOH); A/D and D/A conversions; pulse transfer function representation; time and frequency domain representations; input/output analysis; analysis of sample data systems; stability; design of discrete-time controllers; introduction to state-space representation. Cross listed with ENGR 4723. Prerequisites: ENGR 3721 and ENGR 3722.

ENGR 3730 Robotics (3 Credits)

Introduction to the analysis, design, modeling and application of robotic manipulators. Review of the mathematical preliminaries required to support robot theory. Topics include forward kinematics, inverse kinematics, motion kinematics, trajectory control and planning, and kinetics. Cross listed with ENGR 4730. Prerequisites: ENGR 3611 or ENEE 3111 or permission of instructor.

ENGR 3731 Robotics Lab (1 Credit)

Laboratory that complements the analysis, design, modeling and application of robotic manipulators. Implementation of the mathematical structures required to support robot operation. Topics include forward kinematics, inverse kinematics, motion kinematics, trajectory control and planning and kinetics. Applications include programming and task planning of a manufacturing robot manipulator. Corequisite: ENGR 3730 or permission of instructor.

ENGR 3735 Linear Systems (4 Credits)

This course focuses on linear system theory in time domain. It emphasizes linear and matrix algebra, numerical matrix algebra and computational issues in solving systems of linear algebraic equations, singular value decomposition, eigenvalue-eigenvector and least-squares problems, linear spaces and linear operator theory. It studies modeling and linearization of multi-input/multi-output dynamic physical systems, state-variable and transfer function matrices, analytical and numerical solutions of systems of differential and difference equations, structural properties of linear dynamic physical systems, including controllability, observability and stability. It covers canonical realizations, linear state-variable feedback controller and asymptotic observer design, and the Kalman filter. Cross listed with ENGR 4735. Prerequisites: ENGR 3611, ENGR 3721, and ENGR 3722, or permission of the instructor.

ENGR 3800 Topics in Engineering (1-4 Credits)

Special topics in engineering as announced. May be taken more than once. Prerequisite: varies with offering.

ENGR 3900 Engineering Internship (0-4 Credits)

Students in engineering may receive elective credit for engineering work performed for engineering employers with the approval of the chair or associate chair of the department. At the end of the term, a student report on the work is required, and a recommendation will be required from the employer before a grade is assigned. Junior, senior, or graduate status in engineering is normally required. May not be used to satisfy technical requirements. May be taken more than one for a maximum of 6 quarter hours. Prerequisite: permission of instructor.

CHEM 1240	1	BIOL 1021	1	CHEM 2131	3
MATH 1953	4	CHEM 1020	3	CHEM 2141	1
PHYS 1214	4	CHEM 1250	1	MATH 2080	4
		MATH 2070	4		
		UCC	4		
	16		18		16

Third Year

Fall	Credits	Winter	Credits	Spring	Credits
ENBI 3300	4	ENGR 3201	1	ENBI 3150	4
ENEE 2012	4	ENBI 3200	4	BIOL 3242	0-5
BIOL 2120	4	BIOL 3241	5	CHEM 2453	3
BIOL 2121	1	CHEM 2452	3	CHEM 2463	1
CHEM 2451	3	CHEM 2462	1	UCC	4
CHEM 2461	1	PSYC 1001	4		
	17		18		12-17

Fourth Year

Fall	Credits	Winter	Credits	Spring	Credits
ENGR 3313	2	ENGR 3202	1	ENGR 3333	3
ENBI 3801	4	ENGR 3323	3	ENBI 3700	4
BIOL 2090	4	BIOL 2510	4	Engineering Elective	4
Advanced Seminar	4	BIOL 2511	1	Engineering Elective	4
CHEM 3811	3	CHEM 3812	3		
		UCC	4		
	17		16		15

Total Credits: 197-202