

Bachelor of Science in Electrical Engineering

Program Description

The Department of Electrical Engineering at Mines strives to produce leaders who serve the profession, the global community, and society. Students attain technical expertise while completing coursework and projects reflective of modern technology trends. Students consider the broader impacts of engineering solutions on society and human lives. Fundamental and applied engineering research in power and renewable energy, data sciences and control systems, and RF and wireless communications are offered which support the university's mission of "earth, energy, and environment." At the undergraduate level, the department focuses specialty areas on antennas and wireless communications, information and system sciences, integrated circuits and electronics, and power and energy systems. At the graduate level, the department provides educational and research opportunities in three selected topical areas: 1) compressive sensing and data analysis, 2) energy systems and power electronics, and 3) antennas and wireless communications. Both undergraduate and graduate programs are characterized by strong ties with industrial partners (locally and nationally) that provide resources for students, laboratories, research projects, and ultimately career paths for our students.

Program Education Objectives

The Electrical Engineering program contributes to the educational objectives described in the Mines' Graduate Profile. In addition, the Electrical Engineering Program at Mines has established the following program educational objectives:

Within three years of attaining the BSEE degree:

1. Graduates will be applying their professional Electrical Engineering skills and training in their chosen field or will be successfully pursuing a degree.
2. Graduates will be situated in growing careers, generating new knowledge and exercising professional leadership.
3. Graduates will be contributing to the needs of society through professional practice, research and service.

Student Outcomes

To accomplish these objectives, the Electrical Engineering program has adopted the following Student Outcomes (SO) articulated by ABET:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. an ability to 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.
3. an ability to communicate effectively with a range of audiences.
4. an ability to 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.

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

These Program Educational Objectives and Student Outcomes can be found on the Electrical Engineering Department's website under the Colorado School of Mines website.

ABET Accreditation Status

The Bachelor of Science in Electrical Engineering is accredited by the Engineering Accreditation Commission of ABET, <https://www.abet.org/>, under the commission's General Criteria and Program Criteria for Electrical, Computer, Communications, Telecommunication(s) Engineering and Similarly Named Engineering Programs.

Primary Contact

Christine Monroe, Department Manager
 (303) 384-2465
cmonroe@mines.edu

<https://electrical.mines.edu/>

Bachelor of Science in Electrical Engineering Degree Requirements:

First Year		lec	lab	sem.hrs
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
Science Elective	CBEN110, GEGN101, CHGN122, or CHGN125			4.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
PHGN100	PHYSICS I - MECHANICS			4.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
CSC1128	COMPUTER SCIENCE FOR STEM			3.0
				31.0
Sophomore		lec	lab	sem.hrs
Fall				
HASS215	FUTURES			3.0
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS (Distributed Science 3)			4.0

CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
SUCCESS AND WELLNESS				1.0
				15.0

Spring		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS			3.0
EENG284	DIGITAL LOGIC			4.0
EENG281	ELECTRICAL CIRCUITS			3.0
EENG282	ELECTRICAL CIRCUITS LABORATORY			1.0
Free Elective				3.0
MATH332	LINEAR ALGEBRA			3.0
				17.0

Junior

Fall		lec	lab	sem.hrs
EENG307	INTRODUCTION TO FEEDBACK CONTROL SYSTEMS			3.0
EENG310	INFORMATION SYSTEMS SCIENCE I			3.0
EENG383	EMBEDDED SYSTEMS			4.0
EENG391	FIELD SESSION – COMPUTATIONAL METHODS FOR ELECTRICAL ENGINEERS			1.0
EENG386	FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS			3.0
				17.0

Spring		lec	lab	sem.hrs
EENG385	ELECTRONIC DEVICES AND CIRCUITS			4.0
EENG311	INFORMATION SYSTEMS SCIENCE II			3.0
EENG389	FUNDAMENTALS OF ELECTRIC MACHINERY			4.0
EE Elective	Electrical Engineering Elective *			3.0
EENG350	ELECTRICAL ENGINEERING INTEGRATION AND DESIGN			3.0
				17.0

Senior

Fall		lec	lab	sem.hrs
CAS Elective	Culture and Society (CAS) Mid-Level Restricted Elective			3.0
CAS Elective	Culture and Society (CAS) Mid-Level Restricted Elective			3.0
EDNS491	CAPSTONE DESIGN I			3.0
EE Elective	Electrical Engineering Elective *			3.0
EE Elective	Electrical Engineering Elective *			3.0
EENG393	FIELD SESSION – PRINTED CIRCUIT BOARD DESIGN### or EENG 394			1.0
				16.0

Spring		lec	lab	sem.hrs
CAS Elective	Culture and Society (CAS) 400-Level Restricted Elective			3.0
EDNS492	CAPSTONE DESIGN II			3.0
EE Elective	Electrical Engineering Elective *			3.0
EE Elective	Electrical Engineering Elective *			3.0
Free Elective				3.0
				15.0

Total Semester Hrs: 128.0

* Electrical Engineering students are required to take five Electrical Engineering electives from an approved list. See below for guidelines and the list of Electrical Engineering electives:

Electrical Engineering Electives:

These Electrical Engineering electives are open to all EE students. The interest pathways they fall under are: Information and Systems Science (ISS), Power and Energy Systems (PES), Integrated Circuits and Electronics (ICE), and Antennas and Wireless Communications (AWC).

Electrical Engineering students are required to complete 15 credits of Electrical Engineering electives. At least 9 credits out of the 15 must be 400-level or higher EENG-prefix courses.

EENG411	DIGITAL SIGNAL PROCESSING	3.0
EENG415	DATA SCIENCE FOR ELECTRICAL ENGINEERING	3.0
EENG417	MODERN CONTROL DESIGN	3.0
EENG421	SEMICONDUCTOR DEVICE PHYSICS AND DESIGN	3.0
EENG423	INTRODUCTION TO VLSI DESIGN	3.0
EENG425	INTRODUCTION TO ANTENNAS	3.0
EENG427	WIRELESS COMMUNICATIONS	3.0
EENG428	COMPUTATIONAL ELECTROMAGNETICS	3.0
EENG430	PASSIVE RF & MICROWAVE DEVICES	3.0
EENG433	ACTIVE RF & MICROWAVE DEVICES	3.0
EENG437	INTRODUCTION TO COMPUTER VISION	3.0
EENG470	INTRODUCTION TO HIGH POWER ELECTRONICS	3.0
EENG475	INTERCONNECTION OF RENEWABLE ENERGY	3.0
EENG480	POWER SYSTEMS ANALYSIS	3.0
EENG484	ADVANCED DIGITAL DESIGN	3.0
CSCI341	COMPUTER ORGANIZATION	3.0
CSCI410	ELEMENTS OF COMPUTING SYSTEMS	3.0
CSCI440	PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS	3.0
CSCI442	OPERATING SYSTEMS	3.0
CEEN405	NUMERICAL METHODS FOR ENGINEERS	3.0
MEGN441	INTRODUCTION TO ROBOTICS	3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS	3.0
MEGN330	INTRODUCTION TO BIOMECHANICAL ENGINEERING	3.0
MEGN465	ELECTRIC VEHICLE POWERTRAIN SYSTEMS	3.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0

PHGN320	MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS	4.0
PHGN435	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
PHGN440	SOLID STATE PHYSICS	3.0
PHGN441	SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA	3.0
PHGN462	ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS	3.0

*EE graduate level courses may count towards undergraduate Electrical Engineering Electives; however, undergraduate students must secure instructor approval to enroll in graduate level courses and a course exception request is required for graduate courses to fulfill undergraduate EE electives. Additional 400-level and graduate-level classes taught by faculty in the EE department may be considered on a case-by-case basis as Electrical Engineering electives. Talk to your advisor for further guidance.

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

- EENG100 through EENG699 inclusive
- EDNS491 (EGGN491)
- EDNS492 (EGGN492)

Combined BS/MS in Electrical Engineering

The Department of Electrical Engineering offers a Combined Bachelor of Science/Master of Science program in Electrical Engineering that enables students to begin working on an MS degree while completing their BS degree. Students enrolled in Mines' combined undergraduate/graduate program may double count up to six credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with "B-" or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

Students must be admitted into the combined BS/MS degree program at least one term before their expected graduation date. For example: Apply to the spring 2025 entry term on your Combined Application if you are graduating in May of 2025. This application will be completed in the fall of 2024. Students may apply as early as the first semester of their junior year, upon completion of 60 hours of undergraduate course work. In order to apply for the combined program, a graduate school application must be submitted, and as long as the undergraduate portion of the program is successfully completed and the student has a GPA above 3.0, the student is admitted to the non-thesis Master of Science degree program in Electrical Engineering.

Students are required to take an additional 30 credits for the MS degree. Students should follow the MS non-thesis degree requirements based on their track in selecting appropriate graduate degree courses. Students may switch from the combined program which includes a non-thesis Master of Science degree to an MS degree with a thesis optional, however, if students change degree programs they must satisfy all degree requirements for the MS with thesis degree.

Combined Engineering Physics Baccalaureate and Electrical Engineering Master's Degrees

The Department of Electrical Engineering, in collaboration with the Department of Physics, offers a five-year program in which students have the opportunity to obtain specific engineering skill to complement their physics background. Physics students in this program fill in their technical and free electives over their standard four-year Engineering Physics BS program with a reduced set of Electrical Engineering classes. At the end of the fourth year, the student is awarded an Engineering Physics BS degree. Course schedules for this five-year program can be obtained in the Physics departmental offices.

COURSES

EENG198. SPECIAL TOPICS. 1-6 Semester Hr.

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG199. INDEPENDENT STUDY. 1-6 Semester Hr.

Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Variable credit; 1 to 6 credit hours. Repeatable for credit. Prerequisites: "Independent Study" form must be completed and submitted to the Registrar.

EENG281. ELECTRICAL CIRCUITS. 3.0 Semester Hrs.

This course provides an engineering science analysis of electrical circuits. DC and AC (single-phase and three-phase) networks are presented. Transient analysis of RC and RL circuits is studied as is the analysis of circuits in sinusoidal steady-state using phasor concepts. The following topics are included: DC and AC circuit analysis, current and charge relationships. Ohm's Law, resistors, inductors, capacitors, equivalent resistance and impedance, Kirchhoff's Laws, Thevenin and Norton equivalent circuits, superposition and source transformation, power and energy, maximum power transfer, first order transient response, algebra of complex numbers, phasor representation, time domain and frequency domain concepts, and steady-state analysis of single-phase and three-phase ac power circuits. 3 hours lecture. Prerequisite: PHGN200.

Course Learning Outcomes

- Define basic electrical circuit components and explain how they are used to create functional electrical circuits.
- Analyze DC RLC circuits using the circuit analysis techniques of the Node-Voltage method, the Mesh-Current method, Thevenin & Norton Equivalent Source Transformations, and Superposition.
- Solve DC circuits containing Operational Amplifiers using both the ideal and the practical Op Amp models.
- Analyze RC, RL, and RLC circuits for their transient natural and step responses.

- Analyze AC, DC and transient circuits for basic power and energy concepts.
- Perform steady-state analysis of AC RLC circuits using the frequency domain concepts of phasors and impedance employing the circuit analysis techniques of the Node-Voltage Method, the Mesh-Current Method, Thevenin & Norton Equivalent Source Transformations, Delta-Wye Transforms and Superposition.
- Solve AC circuits including those containing linear and ideal transformers using phasor methods.

EENG282. ELECTRICAL CIRCUITS LABORATORY. 1.0 Semester Hr.

This laboratory course covers hands-on experiments in electrical circuits, including basic DC resistive circuits, operational amplifier circuits, oscilloscope fundamentals, transient analysis of RC, RL, and RLC circuits, steady-state analysis of sinusoidal AC networks, and power factor correction simulations using a commercial circuit analysis software package. 3 hours lab; 1 semester hours. Prerequisite: PHGN200. Corequisite: EENG281.

Course Learning Outcomes

- Define basic electrical circuit components and explain how they are used to create functional electrical circuits.
- Analyze DC RLC circuits using the circuit analysis techniques of the Node-Voltage method, the Mesh-Current method, Thevenin & Norton Equivalent Source Transformations, and Superposition.
- Solve DC circuits containing Operational Amplifiers using both the ideal and the practical Op Amp models.
- Analyze RC, RL, and RLC circuits for their transient natural and step responses.
- Analyze AC, DC and transient circuits for basic power and energy concepts.
- Perform steady-state analysis of AC RLC circuits using the frequency domain concepts of phasors and impedance employing the circuit analysis techniques of the Node-Voltage Method, the Mesh-Current Method, Thevenin & Norton Equivalent Source Transformations, Delta-Wye Transforms and Superposition.
- Solve AC circuits including those containing linear and ideal transformers using phasor methods.

EENG284. DIGITAL LOGIC. 4.0 Semester Hrs.

This course is an introduction to digital logic design. Students will start to learn how to design combinational logic circuit using Kmaps, manipulate these expressions using Boolean algebra and then produce basic building blocks like decoders and adders. Next students will focus on sequential logic circuits with basic memory elements, then design sequential building blocks like counters and registers and then to design finite state machines. Students will then learn how to combine basic building blocks with finite state machines to create complex functionality. Students will implement their design using a hardware description language and download these designs on FPGAs. Prerequisite: CSCI261 (C- or better) or CSCI200 (C- or better). Co-requisite: EENG282 or EENG281 or PHGN215.

Course Learning Outcomes

- Convert between numbering representations.
- Design a combinational logic circuit from a word statement to a circuit diagram.
- Manipulate a logic function in any of its representations; word statement, truth table, symbolic, and circuit diagram.

- Determine SOPmin and POSmin realizations of logic function with or without don't cares.
- Build and operate adders, comparators, multiplexers and decoders.
- Determine output behavior of D,T,SR,JK; latches, clock latches and flip flops.
- Build and operate registers, shift registers, counters, tri-state logic and RAMs.
- Design Finite State Machines using a dense or Ones Hot encoding.
- Implement complex digital systems using the datapath and control design approach.

EENG298. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG299. INDEPENDENT STUDY. 0.5-6 Semester Hr.

Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Variable credit; 1 to 6 credit hours. Repeatable for credit. Prerequisite: Independent Study form must be completed and submitted to the Registrar.

EENG307. INTRODUCTION TO FEEDBACK CONTROL SYSTEMS. 3.0 Semester Hrs.

System modeling through an energy flow approach is presented, with examples from linear electrical, mechanical, fluid and/or thermal systems. Analysis of system response in both the time domain and frequency domain is discussed in detail. Feedback control design techniques, including PID, are analyzed using both analytical and computational methods. Prerequisite: EENG281 or EENG282 or PHGN215 (C- or better) and MATH225 or MATH235.

Course Learning Outcomes

- Develop mathematical models for linear dynamic systems (mechanical, electrical, fluid, and/or thermal).
- Analyze and predict the behavior of linear systems using both time domain and frequency domain tools.
- Design feedback compensators to achieve a specified performance criterion using both time domain and frequency domain techniques.
- Analyze and design feedback control systems using Matlab.

EENG310. INFORMATION SYSTEMS SCIENCE I. 3.0 Semester Hrs.

Equivalent with EENG388,

The interpretation, representation and analysis of time-varying phenomena as signals which convey information and noise; applications are drawn from filtering, audio and image processing, and communications. Topics include convolution, Fourier series and transforms, sampling and discrete-time processing of continuous-time signals, modulation, and z-transforms. Prerequisite: EENG281 or EENG282 (C- or better), MATH225 or MATH235. Corequisite: EENG391.

Course Learning Outcomes

- Compute and interpret the spectrum of continuous and discrete-time signals.
- Determine the effect of converting between continuous and discrete-time signals, and choose sampling rates using the guidelines of the Nyquist sampling theorem.

- Determine the response of a discrete time system using convolution, z-transforms, or frequency response techniques.
- Determine the response of a continuous time system using convolution, Fourier Transforms or frequency response techniques.

EENG311. INFORMATION SYSTEMS SCIENCE II. 3.0 Semester Hrs.

This course covers signals and noise in electrical systems. Topics covered include information theory, signal to noise ratio, random variables, probability density functions, statistics, noise, matched filters, coding and entropy, power spectral density, and bit error rate. Applications are taken from radar, communications systems, and signal processing. Prerequisite: EENG310 and EENG391. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Apply probability concepts such probability mass functions, probability density functions, expectation, variance, independence, conditional probability, Bayes rule, and the central limit theorem in the context of discrete and continuous random variables.
- Use concepts from information theory to quantify the amount of information in a random message, construct binary codebooks for encoding random messages, and quantify the information capacity of simple communication channels.
- Use statistical concepts to characterize and analyze random signals, noise, and datasets, understanding the role of the Gaussian distribution in random noise models, the role of autocorrelation functions and power spectral densities for characterizing random processes, and the role of matched filtering for binary hypothesis testing.
- Compute the bit error rate of certain digital communication systems employing binary signaling over analog communication channels in the presence of additive white Gaussian noise.

EENG340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

Supervised, full-time engineering- related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Engineering Division Faculty Co-op Advisor prior to enrolling to clarify the educational objectives for their individual Co-op program. 3 semester hours credit will be granted once toward degree requirements. Credit earned in EENG340, Cooperative Education, may be used as free elective credit hours or a civil specialty elective if, in the judgment of the Co-op Advisor, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives or civil electives requires the student to submit a 'Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements' form obtained from the Career Center to the Engineering Division Faculty Co-op Advisor. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00.

EENG350. ELECTRICAL ENGINEERING INTEGRATION AND DESIGN. 3.0 Semester Hrs.

This laboratory is a semester-long design and build activity centered around a challenge problem that varies from year to year. Solving this problem requires the design and prototyping of a complex system and utilizes concepts from multiple electrical engineering courses. Students work in intra-disciplinary teams to build modular sub-systems and integrate them to a complete system. Prerequisites: EENG307, EENG383.

Course Learning Outcomes

- Design and debug integrated systems as an intradisciplinary team.
- Design experiments and gather data to solve engineering problems and/or demonstrate performance of subsystems or systems.
- Predict the performance of a designed system and verify their predictions experimentally
- Work effectively in intradisciplinary teams to solve engineering problems.
- Engage in reflective learning and demonstrate an ability to engage in life-long learning.

EENG383. EMBEDDED SYSTEMS. 4.0 Semester Hrs.

The design and implementation of systems consisting of analog and digital components with a microcontroller to perform a dedicated task. Student will implement systems using a variety of microcontroller subsystems including timers, PWM, ADC, serial communication subsystems and interrupts. Students will learn embedded systems programming techniques like, fixed-point math, direct digital synthesis, lookup tables, and row scanning. Student will program the microcontroller using a high-level programming language like C or C++. Prerequisite: EENG281 or EENG282 or PHGN215 (C-or better) and EENG284 or PHGN317 (C-or better).

Course Learning Outcomes

- Write C-code to manipulate pins of the PIC.
- Write code to communicate using serial protocols. I can write a program with one or more interrupt sources.
- Write a program with shared variables between main and an ISR.
- Design an anti-alias filter for an ADC.
- Write code to interface to the PIC ADC subsystem.
- Write code to interface to the PIC timer subsystems.
- Build a system to generate analog output from the PIC.
- Write code on the PIC to communicate to a PC.
- Write code to manipulate fixed-point format numbers.
- Design a direct digital synthesis system using a PIC.
- Can search technical documents to find needed information.

EENG385. ELECTRONIC DEVICES AND CIRCUITS. 4.0 Semester Hrs.

Students will study the large signal and small signal behavior of active components including opamps, diodes, bipolar junction transistors, and field effect transistors. Students will explore the frequency response analysis of standard circuit configurations. Students will engage laboratory exercises to compare how well their theoretical analysis compare to the actual circuit. 3 hours lecture; 3 hours lab; 4 semester hours. Prerequisite: EENG307.

Course Learning Outcomes

- Analyze and design a circuit containing one or more diodes.
- Analyze and design a circuit containing resistors and op amps.
- Perform a DC and AC analysis of a circuit containing BJT.
- Analyze and design a circuit containing one or more BJTs.
- Analyze and design a circuit containing a MOSFET.
- Derive the transfer function for a circuit.
- Use a Bode plot to predict circuit behavior.
- Produce a Bode plot for a circuit using a test and measurement equipment in the laboratory.
- Assemble a circuit on a PCB using the equipment in the laboratory.
- Analyze and design a circuit consisting of several building blocks.

EENG386. FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS. 3.0 Semester Hrs.

This course introduces electromagnetic theory with a focus on its practical applications. It begins with a thorough review of vector calculus, coordinate systems, and key theorems. Following this foundation, an inductive approach is employed, commencing with the first principles of electrostatics and magnetostatics (Coulomb's and Biot-Savart laws) progressing to the derivation of Maxwell's equations by incorporating Faraday's Law and the concept of displacement currents. Key topics covered include the principles underlying electric generators, AC and DC motors. This groundwork facilitates the development of circuit theory, including the establishment of conditions for its validity. The course culminates with an introduction to transmission line theory, impedance matching, and the utilization of the Smith Chart. 3 hours lecture; 3 semester hours. Prerequisite: EENG281 (C- or better) or EENG282 (C- or better), and MATH225 or MATH235.

Course Learning Outcomes

- Apply vector algebra to solve problems in Cartesian, cylindrical, and spherical coordinate systems.
- Analyze scalar and vector functions by computing their gradient, divergence, and curl across primary coordinate systems.
- Evaluate electric and magnetic fields, potentials, and associated properties using principles such as Gauss's law, the Biot-Savart law, and Ampère's law.
- Calculate capacitance, inductance, and power transfer in various electromagnetic configurations, including transmission lines.
- Demonstrate the application of integral theorems, such as the divergence theorem, Stokes's theorem, and Faraday's law, in electromagnetic scenarios.
- Interpret transmission-line behavior using tools like the Smith chart to assess parameters such as impedance, reflection coefficients, and standing-wave patterns.

EENG389. FUNDAMENTALS OF ELECTRIC MACHINERY. 4.0 Semester Hrs.

This course provides an engineering analysis of electrical machines. The following topics are included: review of three-phase AC circuit analysis, magnetic circuit concepts and materials, transformer analysis and operation, modelling, steady-state analysis of rotating machines, synchronous and poly-phase induction motors, and DC machines and laboratory study of external characteristics of machines and transformers. Prerequisite: EENG281 (C- or better) or EENG282 (C- or better). 3 hours lecture, 3 hours lab; 4 semester hours.

Course Learning Outcomes

- Explain the principles of operation of energy conversion devices (Transformers, 3-phase AC Synchronous and Induction machines, DC machines), and machine modes of operation (motoring, generation).
- Illustrate and describe a device equivalent circuit model and relate its parameters and terminal inputs/outputs to those of an actual device.
- Predict and analyze external operational characteristics (current, voltage, power, energy, torque, speed, losses, efficiency, etc.) of a system with an energy conversion device using the developed electric circuit models.
- Measure the values of a device equivalent circuit model parameters and its external operational characteristics (current, voltage, power, energy, torque, speed, losses, efficiency, etc.) under specific mode of operation, as detailed in a Lab experiment.

- Implement the circuit model of a system with an energy conversion device in a computer tool (MATLAB/SIMULINK or as specified) using available values of the circuit model parameters to calculate the system external operational characteristics.

EENG391. FIELD SESSION – COMPUTATIONAL METHODS FOR ELECTRICAL ENGINEERS. 1.0 Semester Hr.

Students will learn computational methods for common tasks in electrical engineering such as creating and plotting signals and data, analyzing and implementing digital filters, numerically computing integrals, solving differential equations, and simulating dynamical systems. Prerequisite: EENG281 or EENG282 (C- or better), MATH225 or MATH235. Co-requisite: EENG310.

Course Learning Outcomes

- Create and plot signals and data using MATLAB.
- Use MATLAB to analyze and implement digital filters.
- Use MATLAB and Simulink for integration, differentiation, and simulation of dynamical systems.

EENG393. FIELD SESSION – PRINTED CIRCUIT BOARD DESIGN. 1.0 Semester Hr.

Students will learn how to design, fabricate, and solder a printed circuit board (PCB) from concept to implementation. In addition to teaching best design practices, the course will address the variety of real-world constraints that impact the manufacturing of electrical circuits on PCBs. 1 hour lecture; 2 hours lab; 1 semester hour. Prerequisite: EENG383 or EENG385.

Course Learning Outcomes

- Create a schematic.
- Create a footprint.
- Create a layout.
- Create fabrication files.
- Assemble a PCB with SMT components.
- Troubleshoot an analog circuit.

EENG394. FIELD SESSION – ANTENNAS AND WIRELESS COMMUNICATIONS. 1.0 Semester Hr.

This course provides the basic theories of electromagnetics, antennas, and wireless communications. Hands on experience will be developed during the projects assigned in the class to design antennas and passive microwave devices. 0.5 hours lecture; 1.5 hours lab; 1 semester hour.

Course Learning Outcomes

- Learn how to select different antennas to meet the design requirements and application.
- Perform detailed design analysis in the context of electromagnetic simulation.
- Establish and develop error analysis associated with the design through simulation.
- Fabricate simple antennas and passive microwave devices.
- Perform the basic measurements in an antenna lab.
- Write a professionally acceptable technical report.

EENG395. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

(I, II) Individual research project for freshman, sophomores or juniors under direction of a member of the departmental faculty. Written report required for credit. Seniors should take EENG495 instead of EENG395. Repeatable for credit. Variable credit; 1 to 3 semester hours.

Course Learning Outcomes

- Students will successfully complete a research project under direction of a member of the departmental faculty.

EENG398. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 0-6 Semester Hr.

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG399. INDEPENDENT STUDY. 1-6 Semester Hr.

Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Variable credit; 1 to 6 credit hours. Repeatable for credit. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar.

EENG411. DIGITAL SIGNAL PROCESSING. 3.0 Semester Hrs.

This course introduces the mathematical and engineering aspects of digital signal processing (DSP). An emphasis is placed on the various possible representations for discrete-time signals and systems (in the time, z -, and frequency domains) and how those representations can facilitate the identification of signal properties, the design of digital filters, and the sampling of continuous-time signals. Advanced topics include sigma-delta conversion techniques, multi-rate signal processing, and spectral analysis. The course will be useful to all students who are concerned with information bearing signals and signal processing in a wide variety of application settings, including sensing, instrumentation, control, communications, signal interpretation and diagnostics, and imaging. Prerequisite: EENG310. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Characterize discrete-time signals and systems in the time, z -, and frequency domains for DSP hardware.
- Convert analog signals for digital processing, addressing aliasing, sampling, and reconstruction challenges.
- Analyze digital filters for hardware implementation, accounting for fixed-point arithmetic and quantization noise.
- Compute DFT efficiently while considering quantization impacts in frequency analysis.
- Implement discrete-time systems, understanding fixed- and binary-point representations.
- Quantify and minimize quantization errors in DSP operations using scaling and rounding techniques to enhance hardware accuracy.

EENG415. DATA SCIENCE FOR ELECTRICAL ENGINEERING. 3.0 Semester Hrs.

This course presents a comprehensive exposition of the theory, methods, and algorithms for data analytics as related to power and energy systems. It will focus on (1) techniques for performing statistical inference based on data, (2) methods for predicting future values of data, (3) methods for classifying data instances into relevant classes and clusters, (4) methods for building, training and testing artificial neural networks, and (5) techniques for evaluating the effectiveness and quality of a data analytics model. Prerequisite: EENG311.

Course Learning Outcomes

- Describe sources and types of data in modern energy and automation systems.
- Apply R commands to analyze data and develop data analytics models.

- Apply statistical analysis tools to process raw data.
- Derive statistical inferences about a population.
- Assign data instances to classes.
- Apply regression techniques to model the relationship among variables of interest.
- Design artificial neural networks for various prediction applications.
- Evaluate the performance of a developed model using appropriate metrics.

EENG417. MODERN CONTROL DESIGN. 3.0 Semester Hrs.

Control system design with an emphasis on observer-based methods, from initial open-loop experiments to final implementation. The course begins with an overview of feedback control design technique from the frequency domain perspective, including sensitivity and fundamental limitations. State space realization theory is introduced, and system identification methods for parameter estimation are introduced. Computerbased methods for control system design are presented. Prerequisite: EENG307. 3 lecture hours, 3 semester hours.

Course Learning Outcomes

- Model and analyze single-input single-output (SISO) systems using both transfer function and state space realizations in continuous- and discrete-time.
- Design and test controllers for these systems.
- Differentiate between continuous time and discrete time signals and systems (relating to modeling, analysis, and design).
- Model, analyze, and design feedback control systems using MATLAB and Simulink in both the time and frequency domains.

EENG421. SEMICONDUCTOR DEVICE PHYSICS AND DESIGN. 3.0 Semester Hrs.

This course will explore the field of semiconductors and the technological breakthroughs which they have enabled. We will begin by investigating the physics of semiconductor materials, including a brief foray into quantum mechanics. Then, we will focus on understanding pn junctions in great detail, as this device will lead us to many others (bipolar transistors, LEDs, solar cells). We will explore these topics through a range of sources (textbooks, scientific literature, patents) and discuss the effects they have had on Western society. As time allows, we will conclude with topics of interest to the students (possibilities include quantum devices, MOSFETs, lasers, and integrated circuit fabrication techniques). Prerequisite: PHGN200. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Understand the phenomena in semiconductor devices that lead to their terminal characteristics (I-V and C-V curves) relevant for circuit applications.
- Analyze the transport of charge carriers in semiconductor devices when subjected to electromagnetic fields and predict their behavior.
- Design models for semiconductor devices that correlate terminal characteristics with device geometry, material parameters such as doping, mobility, and carrier lifetime, and ambient conditions including temperature.
- Simulate device characteristics using TCAD tools like Silvaco Victory to validate and the developed models.

EENG423. INTRODUCTION TO VLSI DESIGN. 3.0 Semester Hrs.

This is an introductory course that will cover basic theories and techniques of digital VLSI (Very Large Scale Integrated Circuits) design and CMOS technology. The objective of this course is to understand the theory and design of digital systems at the transistor level. The course will

cover MOS transistor theory, CMOS processing technology, techniques to design fast digital circuits, techniques to design power efficient circuits, standard CMOS fabrications processes, CMOS design rules, and static and dynamic logic structures. Prerequisites: EENG281 (C- or better) or EENG282 (C- or better), and EENG284 (C- or better). 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Analyze the effects of reducing channel length and feature sizes in transistor technology on circuit performance.
- Characterize the key delay parameters of a circuit to evaluate its efficiency.
- Design a circuit that meets specified functionality and speed requirements.
- Identify the critical path in a combinational circuit to optimize performance.
- Convert a combinational block into a pipelined circuit to enhance processing speed.
- Calculate the maximum operating frequency of the designed circuit to ensure optimal performance. Simulate the CMOS circuits using Cadence tools.

EENG424. ELECTROMAGNETIC FIELDS AND WAVES. 3.0 Semester Hrs.

This course provides an introduction to electromagnetic fields and waves and their applications in antennas, radar, high-frequency electronics, and microwave devices. The time-varying form of electromagnetic fields and the use of sinusoidal time sources to create time-harmonic electromagnetic fields will be covered first, followed by coverage of plane electromagnetic waves formulation and reflection and transmission from different surfaces. Finally, the application of guided electromagnetic waves will be covered through the study of transmission lines, waveguides, and their applications in microwave systems. 3 hours lecture; 3 semester hours. Prerequisites: EENG386.

Course Learning Outcomes

- Understand and learn differential and integral forms of Maxwell's equations.
- Develop formulation for plane electromagnetic waves and use them to design electromagnetic devices.
- Build electromagnetic models and use them to solve electromagnetic problems.
- Develop computer programs to visualize electromagnetic fields such as waveguide modes or signal propagation on transmission lines.

EENG425. INTRODUCTION TO ANTENNAS. 3.0 Semester Hrs.

This course provides an introduction to antennas and antenna arrays. Theoretical analysis and use of computer programs for antenna analysis and design will be presented. Experimental tests and demonstrations will also be conducted to complement the theoretical analysis. Students are expected to use MATLAB to model antennas and their performance. Prerequisites: EENG386.

Course Learning Outcomes

- Develop a good understanding of what approximations are used before designing an antenna.
- Select the proper antenna type according to the required specifications.
- Develop MATLAB programs to aid in the design of antennas and antenna arrays.
- Complete basic analysis and design of an antenna project.

- Design and build a microstrip patch antenna and perform input impedance measurements.

EENG427. WIRELESS COMMUNICATIONS. 3.0 Semester Hrs.

This course provides the tools needed to analyze and design a wireless system. Topics include link budgets, satellite communications, cellular communications, handsets, base stations, modulation techniques, RF propagation, coding, and diversity. Students are expected to complete an extensive final project. Prerequisite: EENG311 or MATH201 and EENG310.

Course Learning Outcomes

- Calculate the link budget of a wireless communications system.
- Estimate the effects of wireless propagation mechanisms on signals.
- Apply statistical channel models to wireless channels.
- Identify the antenna parameters that are relevant to wireless communications.
- Describe, analyze, and understand the engineering tradeoffs associated with modulation, coding, multiple access, and spread spectrum techniques.
- Write a paper and present a project on an advanced wireless communications topic not covered in class.

EENG428. COMPUTATIONAL ELECTROMAGNETICS. 3.0 Semester Hrs.

This course provides the basic formulations and numerical solutions for static and full wave electromagnetic problems. Static problems are based on Laplace and Poisson equations while full wave electromagnetic problems are based on differential and integral forms of Maxwell's equations. Different numerical methods will be introduced such as: finite difference, finite difference frequency domain, finite difference time domain, and method of moments. The numerical development and implementation of these methods using MATLAB will be conducted to solve practical problems. 3 hours lecture; 3 semester hours. 3 hours lecture; 3 semester hours. Prerequisite: EENG386.

Course Learning Outcomes

- Learn how to develop MATLAB problems for electromagnetic problems.
- Learn the different finite difference (FD) mathematical approximations of the derivatives for adaptation to numerical solutions of Maxwell's equations.
- Learn how to convert differential equations into discretized equations and arrange them to form a set of linear equations.
- Learn how to use the finite difference FD for solving electrostatic problems.
- Learn the finite difference frequency domain (FDFD) method and its proper implementations for 1D and 2D electromagnetic problems.
- Learn the finite difference time-domain (FDTD) method and its proper implementations for 2D and 3D electromagnetic problems.
- Learn how to solve antenna problems using the FDTD method.
- Learn how to derive and solve wave propagation through multilayered media.
- Learn how to derive and solve the scattering by circular cylinder.
- Be able to write a good professional project report.

EENG430. PASSIVE RF & MICROWAVE DEVICES. 3.0 Semester Hrs.

This course introduces the basics of passive radio-frequency (RF) and microwave circuits and devices which are the building blocks of modern communication and radar systems. The topics that will be studied are

microwave transmission lines and waveguides, microwave network theory, microwave resonators, power dividers, directional couplers, hybrids, RF/microwave filters, and phase shifters. Students will also learn how to design and analyze passive microwave devices using professional CAD software. Moreover, students will learn how to fabricate printed passive microwave devices and test them using a vector network analyzer. Prerequisites: EENG386. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Learn how to analyze transmission line propagation and the effect of discontinuities on the voltages and current distributions.
- Understand transmission line concepts such as reflection coefficient, transmission coefficient, characteristic impedance, impedance, standing-wave ratio, etc.
- Learn how to analyze arbitrary multiport microwave networks using the concepts of S, Z, Y and T parameter matrices.
- Understand the operation principle and analysis of various passive microwave components such as dividers, couplers, resonators and filters.
- Design various passive microwave components considering realistic fabrication constraints with the aid of CAD tools.
- Gain a high level understanding of the operation principle of sub-systems and systems such as radars, transceivers and radiometers, as well as the effects of noise.
- Learn the basics of microwave measurement techniques.

EENG433. ACTIVE RF & MICROWAVE DEVICES. 3.0 Semester Hrs.

This course introduces the basics of active radio-frequency (RF) and microwave circuits and devices which are the building blocks of modern communication and radar systems. The topics that will be studied are RF and microwave circuit components, resonant circuits, matching networks, noise in active circuits, switches, RF and microwave transistors and amplifiers. Additionally, mixers, oscillators, transceiver architectures, RF and monolithic microwave integrated circuits (RFICs and MMICs) will be introduced. Moreover, students will learn how to model active devices using professional CAD software, how to fabricate printed active microwave devices, how a vector network analyzer (VNA) operates, and how to measure active RF and microwave devices using VNAs. 3 hours lecture; 3 semester hours. Prerequisite: EENG385 and EENG430 or EENG530.

Course Learning Outcomes

- Learn how to analyze and design a variety of active RF and microwave devices such as power amplifiers which will improve the students' ability to identify, formulate, and solve engineering problems.
- Understand the basic operation mechanism of transmitters and receivers in communication systems which will improve the students' ability to apply knowledge of mathematics, science, and engineering in a system level problem.
- Gain a basic understanding on how vector network analyzers operate and how to measure active microwave devices which will improve the students' ability to apply knowledge of mathematics, science, and engineering.
- Learn how to model active microwave circuits and devices using a professional CAD tool which will improve the students' ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

EENG437. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.

Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course provides an introduction to this field, covering topics in image formation, feature extraction, location estimation, and object recognition. Design ability and hands-on projects will be emphasized, using popular software tools. The course will be of interest both to those who want to learn more about the subject and to those who just want to use computer imaging techniques. 3 hours lecture; 3 semester hours. Prerequisite: MATH201 or EENG311, MATH332, CSCI261 or CSCI200, Senior level standing.

Course Learning Outcomes

- able to analyze and predict the behavior of image formation, transformation, and recognition algorithms.
- Be able to design, develop, and evaluate algorithms for specific applications.
- Be able to use software tools to implement computer vision algorithms.

EENG470. INTRODUCTION TO HIGH POWER ELECTRONICS. 3.0 Semester Hrs.

Power electronics are used in a broad range of applications from control of power flow on major transmission lines to control of motor speeds in industrial facilities and electric vehicles, to computer power supplies. This course introduces the basic principles of analysis and design of circuits utilizing power electronics, including AC/DC, AC/AC, DC/DC, and DC/AC conversions in their many configurations. 3 hours lecture; 3 semester hours. Prerequisite: EENG282, EENG389.

Course Learning Outcomes

- Analyze power electronics circuits based on waveform distortion, harmonics, average, RMS.
- Calculate the loss curves for power electrons in power electronics switches in circuits.
- Analyze line-frequency diode rectifiers including single-phase half-bridge rectifier, single-phase full-bridge rectifier, three-phase rectifier.
- Analyze simulation results for a single-phase half-bridge inverter, single-phase full-bridge rectifier, and three-phase inverter.
- Implement inverter control including, pulse width modulation (PWM) technique, bidirectional power flow, current control (hysteresis control, fixed switching frequency control), space vector modulation (SVM) technique.

EENG475. INTERCONNECTION OF RENEWABLE ENERGY. 3.0 Semester Hrs.

Equivalent with MEGN475,

This course focuses on different aspects of interconnection of distributed renewable generation resources at the power distribution and transmission levels. Students will have a clear understanding of the source and electrical characteristics of different renewable energy sources and the challenges associated with the integration of renewable generation resources with the current power grid. Hands-on simulation-based case studies will help the students examine the covered topics on realistic power system models and understand how renewable energy interconnection issues affect power and voltage quality. Students will also be introduced to the US electricity markets and the role of renewable energy and energy storage in providing deliverable energy flexibility. The course consists of a mathematical and analytical understanding of

relevant electrical energy conversion systems analysis and modeling issues. Prerequisite: EENG282, EENG389, EENG470.

Course Learning Outcomes

- Learn the basic design components and their functions for the selected energy conversion devices.
- Describe the functions of power electronic inverters and use in solar and wind energy.
- Model renewable energy systems in simulation tools.
- Understand the potential impacts of integrating renewable energy resources into power transmission and distribution systems.
- Analyze system impact and perform case studies using computational tools. Develop modeling and control strategies, implement in PowerWorld and OpenDSS.
- Learn to write technical reports and give technical presentations to summarize the study work and key findings using text and good-quality diagrams/figures.

EENG480. POWER SYSTEMS ANALYSIS. 3.0 Semester Hrs.

3-phase power systems, per-unit calculations, modeling and equivalent circuits of major components, voltage drop, fault calculations, symmetrical components and unsymmetrical faults, system grounding, power-flow, selection of major equipment, design of electric power distribution systems. Prerequisite: EENG389. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Describe the operation principles of the electric power grid.
- Conduct power calculations in single and three-phase circuits.
- Develop models for transformers, generators, and transmission/distribution lines.
- Describe the foundations of fossil fuel and renewable based generation.
- Model the electric demand.
- Determine the requirements for reliable, secure, and efficient power grid operation.
- Identify the key characteristics of deregulated electricity markets.
- Apply numerical techniques to solve the power flow problem.
- Apply the method of symmetrical components to perform fault analysis.

EENG484. ADVANCED DIGITAL DESIGN. 3.0 Semester Hrs.

Design an advanced embedded system utilizing hardware/software co-design. Prerequisites: EENG284 and EENG383.

Course Learning Outcomes

- Design and implement a complex, structured, synthesizable digital system that meets defined requirements.
- Use contemporary software tools to debug a digital system design and verify that a digital system meets defined requirements.
- Analyze and describe the timing, clock, and synchronization requirements for a given digital system.
- Design and implement a digital system using a fully custom-built hardware solution, interfaced to a general-purpose processor.
- Explore hardware/software co-design.

EENG495. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

Individual research project under direction of a member of the departmental faculty. Written report required for credit. Prerequisites: senior-level standing based on credit hours. Variable credit; 1 to 3 semester hours. Repeatable for credit.

Course Learning Outcomes

- Students will successfully complete a research project under direction of a member of the departmental faculty.

EENG497. SPECIAL SUMMER COURSE. 0-15 Semester Hr.

EENG498. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.

Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG499. INDEPENDENT STUDY. 1-6 Semester Hr.

Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Variable credit; 1 to 6 credit hours. Repeatable for credit. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar.

Course Learning Outcomes

Teaching Professor and Interim Department Head

Abd Arkadan

Professors

Peter Aaen

Atef Elsherbeni

Kathryn Johnson

Tyrone Vincent

Michael Wakin

Associate professors

Qihua Huang

Salman Mohagheghi

Assistant professors

Yamuna Phal

Gabriel Santamaria-Botello

Sihua Shao

Teaching Professor

Chris Coulston

Teaching Associate Professors

Hisham Sager

Prachi Sharma

Teaching Assistant Professor

Josue Campos do Prado

Emeriti Professors

Ravel Ammerman

Nigel Middleton

Kevin Moore

Pankaj (PK) Sen

Jeffrey Schowalter

Marcelo Simoes

Emerita Professor

Catherine Skokan