Electrical Engineering

PROGRAM DESCRIPTION

The Department of Electrical Engineering at Mines strives to produce leaders who serve the profession, the global community, and society. In addition to the program's ABET-accredited undergraduate curriculum, students attain technical expertise while completing course work 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 on a select number of subareas in electrical engineering; specifically,
(1) energy systems and power electronics (ESPE),
(2) integrated circuits, computer engineering and electronic systems (ICE),
(3) information and systems sciences (ISS), and
(4) antennas and wireless communications (AWC).

At the graduate level, the department provides educational and research opportunities in three selected topical areas:
(1) compressive sensing, data analysis, control and optimization;
(2) energy systems, electric power, power electronics, renewable energy, machines and drives,
(3) antennas, RF and microwaves, wireless communications, and computational electromagnetics.

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.

BS in Electrical Engineering

PROGRAM EDUCATIONAL 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.

Bachelor of Science in Electrical Engineering Degree Requirements:

Freshman

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<tr>
<th>Fall</th>
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<th>lab sem.hrs</th>
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<tbody>
<tr>
<td>CHGN121</td>
<td>PRINCIPLES OF CHEMISTRY I</td>
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<td>GEGN101</td>
<td>EARTH AND ENVIRONMENTAL SYSTEMS, CBEN 110, CSCI 101, CHGN 122, or CHGN 125 (Distributed Science 1. May not use both CHGN122 and 125)</td>
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<td>CALCULUS FOR SCIENTISTS AND ENGINEERS I</td>
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Spring

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<td>EDNS151</td>
<td>INTRODUCTION TO DESIGN</td>
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<td>PHGN100</td>
<td>PHYSICS I - MECHANICS</td>
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<td>CSCI101</td>
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<td>CALCULUS FOR SCIENTISTS AND ENGINEERS III</td>
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<td>PHGN200</td>
<td>PHYSICS II - ELECTROMAGNETISM AND OPTICS</td>
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Spring

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<td>EENG284</td>
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<td>Junior</td>
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<td>MATH332</td>
<td>LINEAR ALGEBRA</td>
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<td>EENG310</td>
<td>INFORMATION SYSTEMS SCIENCE I</td>
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<td>EENG383</td>
<td>MICROCOMPUTER ARCHITECTURE AND INTERFACING</td>
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<tr>
<td>EENG389</td>
<td>FUNDAMENTALS OF ELECTRIC MACHINERY</td>
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Total Semester Hrs: 129.5

* Electrical Engineering students are required to take three Electrical Engineering Electives from the following list:

**Electrical Engineering Electives:**
Organized by emphasis area. To have emphasis area on official transcript, 12 credits in one area must be completed.

**Information and Systems Sciences**
- EENG411 DIGITAL SIGNAL PROCESSING 3.0
- EENG413 ANALOG AND DIGITAL COMMUNICATION SYSTEMS 4.0
- EENG417 MODERN CONTROL DESIGN 3.0
- EENG427 WIRELESS COMMUNICATIONS 3.0
- EENG437 INTRODUCTION TO COMPUTER VISION 3.0
- MEGN441 INTRODUCTION TO ROBOTICS 3.0

**Energy Systems and Power Electronics**
- EENG390 ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID 3.0
- EENG470 INTRODUCTION TO HIGH POWER ELECTRONICS 3.0
- EENG480 POWER SYSTEMS ANALYSIS 3.0
- EENG481 ANALYSIS AND DESIGN OF ADVANCED ENERGY SYSTEMS 3.0
- EENG489 COMPUTATIONAL METHODS IN ENERGY SYSTEMS AND POWER ELECTRONICS 3.0

**Antennas and Wireless Communications**
- EENG425 INTRODUCTION TO ANTENNAS 3.0
- EENG427 WIRELESS COMMUNICATIONS 3.0
- EENG428 COMPUTATIONAL ELECTROMAGNETICS 3.0
- EENG429 ACTIVE RF & MICROWAVE DEVICES 3.0
- EENG430 PASSIVE RF & MICROWAVE DEVICES 3.0
- EENG486 ELECTROMAGNETIC FIELDS AND WAVES 3.0

**Integrated Circuits and Electronics**
- EENG411 DIGITAL SIGNAL PROCESSING 3.0
- EENG421 SEMICONDUCTOR DEVICE PHYSICS AND DESIGN 3.0
- EENG423 INTRODUCTION TO VLSI DESIGN 3.0
- PHGN435 INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY 3.0

**Electrical Engineering General**
- CEEN405 NUMERICAL METHODS FOR ENGINEERS 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
- MATH335 INTRODUCTION TO MATHEMATICAL STATISTICS 3.0
- MATH455 PARTIAL DIFFERENTIAL EQUATIONS 3.0
- MEGN330 INTRODUCTION TO BIOMECHANICAL ENGINEERING 3.0
- PHGN300 PHYSICS III-MODERN PHYSICS I 3.0
A student must complete at least one semester as a registered graduate student may take beyond the undergraduate degree requirements, but there is no limit on the number of graduate level (500-level and above) courses a student will be at the graduate level. There is no degree requirements for 400-level courses. The remainder of the degree. Up to nine of the 30 credit hours beyond the undergraduate degree. Students are required to take an additional 30 credit hours for the M.S. in Electrical Engineering.

**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 work on a Bachelor of Science and a Master of Science simultaneously. This allows undergraduate students to take courses that will count for their graduate degree requirements, while still finishing their undergraduate degree requirements. This will be especially attractive to students who intend to go on to the graduate program, and have availability in their schedules even while fulfilling the undergraduate requirements. Another advantage is that there is an expedited graduate school application process, as described below.

Students must be admitted into the Combined BS/MS degree program prior to the close of registration of the term in which any course toward the MS degree will be applied. Typically this is the beginning of the student’s Senior year, but students may apply as early as the first semester of their Junior year. Admissions must be granted no later than the end of registration in the last semester of the Senior year. In order to apply for the combined program, a pro forma graduate school application is 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 must take an additional 30 credit hours for the M.S. degree. Up to nine of the 30 credit hours beyond the undergraduate degree requirements can be 400-level courses. The remainder of the courses will be at the graduate level (500-level and above). There is no limit on the number of graduate level (500-level and above) courses a student may take beyond the undergraduate degree requirements, but a student must complete at least one semester as a registered graduate student after completion of the undergraduate degree before being awarded a graduate degree. Students must declare graduate courses through the Registrar’s Office at time of registration. Grades count toward the graduate GPA and must meet the minimum grade requirements (C# or higher) to be counted toward graduation requirements. Courses may not be used to meet undergraduate financial aid requirements. Students will declare course work as regular graduate courses on Admission to Candidacy Form. 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 M.S. degree with a thesis optional, however, if students change degree programs they must satisfy all degree requirements for the M.S. with thesis degree.

**Combined Engineering Physics Baccalaureate and Electrical Engineering Masters 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 B.S. program with a reduced set of Electrical Engineering classes. At the end of the fourth year, the student is awarded an Engineering Physics B.S degree. Course schedules for this five-year program can be obtained in the Physics Departmental Offices.

General CSM Minor/ASI requirements can be found here (catalog.mines.edu/undergraduate/undergraduateinformation/minorasi).

**Electrical Engineering ASI in Electrical Engineering**

The following twelve credit sequence is required for an ASI in Electrical Engineering: (See Minor/ASI section of the Bulletin for all rules for ASIs at Mines.)

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<thead>
<tr>
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<th>Title</th>
<th>Credits</th>
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<tr>
<td>EENG281</td>
<td>INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER</td>
<td>3.0</td>
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<tr>
<td>or PHGN215</td>
<td>ANALOG ELECTRONICS</td>
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<tr>
<td>EENG307</td>
<td>INTRODUCTION TO FEEDBACK CONTROL SYSTEMS</td>
<td>3.0</td>
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</table>

Complete remaining requirements by taking any EENG 300 or 400 level course.

**Minor in Electrical Engineering**

A minimum of eighteen credits are required for a Minor in Electrical Engineering as follows. (See Minor/ASI section of the Bulletin for all rules for minors at Mines.)

Students must complete an eighteen credit hour sequence as described below for a minor in EE. All students seeking a minor in EE will need to take one of two possible versions of Electrical Circuits and EENG 307 (3 credits) after which they can pick an emphasis area to complete the remaining minor requirements. The four emphasis areas are as follows

1. Information Systems and Science (ISS), 18 or 18.5 credits
   - EENG282 ELECTRICAL CIRCUITS 4.0

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<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EENG282</td>
<td>ELECTRICAL CIRCUITS</td>
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</table>

*Additional EENG or CSCI 400 level and graduate level classes taught in the EE department can be considered as tech electives. Talk to your advisor for further guidance. 300 level or higher courses from other departments can be considered by the Department Head.*

**Courses that are included in the GPA**

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<th>Course</th>
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<td>PHGN320</td>
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<td>PHGN440</td>
<td>SOLID STATE PHYSICS</td>
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<tr>
<td>PHGN441</td>
<td>SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA</td>
<td>3.0</td>
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<tr>
<td>PHGN462</td>
<td>ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS</td>
<td>3.0</td>
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or EENG281 & MEGN250

EENG307 INTRODUCTION TO FEEDBACK CONTROL SYSTEMS 3.0
EENG284 DIGITAL LOGIC 4.0
EENG310 INFORMATION SYSTEMS SCIENCE I 4.0
EENG311 INFORMATION SYSTEMS SCIENCE II 3.0

2. Energy Systems and Power (ESPE), 18 credits

EENG282 ELECTRICAL CIRCUITS 4.0
EENG307 INTRODUCTION TO FEEDBACK CONTROL SYSTEMS 3.0
EENG385 ELECTRONIC DEVICES AND CIRCUITS 4.0
EENG386 FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS 3.0
EENG389 FUNDAMENTALS OF ELECTRIC MACHINERY 4.0

3. Digital Systems, 18 or 18.5 credits

EENG282 or EENG281 & MEGN250

EENG307 INTRODUCTION TO FEEDBACK CONTROL SYSTEMS 3.0
EENG284 DIGITAL LOGIC 4.0
EENG383 MICROCOMPUTER ARCHITECTURE AND INTERFACING 4.0
EENG421 SEMICONDUCTOR DEVICE PHYSICS AND DESIGN 3.0
or EENG423 INTRODUCTION TO VLSI DESIGN

4. General Electrical Engineering, 19 or 19.5 credits

EENG282 or EENG281 & MEGN250

EENG307 INTRODUCTION TO FEEDBACK CONTROL SYSTEMS 3.0
EENG284 DIGITAL LOGIC 4.0
EENG310 INFORMATION SYSTEMS SCIENCE I 4.0
EENG385 ELECTRONIC DEVICES AND CIRCUITS 4.0

Professor and Department Head
Atef Elsherbeni, Dobelman Chair

Professors
Randy Haupt
Marcelo Simoes
Pankaj Sen

Associate professors
Kathryn Johnson
Salman Mohagheghi
Michael Wakin

Assistant professors
Payam Nayeri
Gongguo Tang

Teaching Professors
Abd Arkadan
Vibhuti Dave, Assistant Department Head
Jeff Schowalter

Teaching Associate Professors
Stephanie Claussen
Chris Coulston

Research Professor
Mohammed Hadi

Emeritus Professor
Ravel Ammerman

Emerita Professor
Catherine Skokan

Courses
EENG198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) 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.

EENG199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) 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. Prerequisite: “Independent Study” form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.
EENG281. INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER. 3.0 Semester Hrs.
Equivalent with DCGN381, EGGN281, EGGN381.
(I, II) This course provides an engineering science analysis of electrical circuits. DC and single-phase AC networks are presented. Transient analysis of RC, RL, and RLC circuits is studied as is the analysis of circuits in sinusoidal steady-state using phasor concepts. The following topics are included: DC and single-phase 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 ideal transformers. The course features PSPICE, a commercial circuit analysis software package. May not also receive credit for EENG282. Prerequisite: PHGN200. 3 hours lecture; 3 semester hours.

EENG282. ELECTRICAL CIRCUITS. 4.0 Semester Hrs.
(I,II) 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 ideal transformers. May not also receive credit for EENG282. Prerequisite: PHGN200. 3 hours lecture; 4 semester hours.

EENG284. DIGITAL LOGIC. 4.0 Semester Hrs.
Equivalent with EGGN284, EGGN384.
(I, II) Fundamentals of digital logic design. Covers combinational and sequential logic circuits, programmable logic devices, hardware description languages, and computer-aided design (CAD) tools. Laboratory component introduces simulation and synthesis software and hands-on hardware design. Prerequisites: CSCI261. Co-requisites: EENG282 or EENG281 or PHGN215. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG298. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.
(I, II) 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.

EENG299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) 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. Prerequisite: “Independent Study” form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG307. INTRODUCTION TO FEEDBACK CONTROL SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN307, EGGN407.
(I, II) 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. Prerequisites: EENG281 or EENG282 or PHGN215, and MATH225. 3 hours lecture; 3 semester hours.

EENG310. INFORMATION SYSTEMS SCIENCE I. 4.0 Semester Hrs.
Equivalent with EENG388, EGGN388.
(I, II) 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. Prerequisites: (EENG281 or EENG282 or PHGN215) and MATH225. 3 hours lecture; 1 hour recitation, 4 semester hours.

EENG311. INFORMATION SYSTEMS SCIENCE II. 3.0 Semester Hrs.
(I, II) 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. 3 hours lecture; 3 semester hours.

EENG334. ENGINEERING FIELD SESSION, ELECTRICAL. 3.0 Semester Hrs.
Equivalent with EGGN334.
(S) Experience in the engineering design process involving analysis, design, and simulation. Students use engineering, mathematics and computers to model, analyze, design and evaluate system performance. Teamwork emphasized. Prerequisites: EENG284 [C- or better], EENG307, EENG310, PHGN215, and MATH225. 3 hours lecture; 3 semester hours.

EENG335. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
Equivalent with EGGN340, EGGN340E.
(I,II,S) Supervised, full-time engineering related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Department Head prior to enrolling to clarify the educational objectives for their individual Co-op program. Prerequisites: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 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 if, in the judgment of the Department Head, 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 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 Department Head.
EENG383. MICROCOMPUTER ARCHITECTURE AND INTERFACING. 4.0 Semester Hrs.
Equivalent with EGGN383, EGGN482.
(I, II) Microprocessor and microcontroller architecture focusing on hardware structures and elementary machine and assembly language programming skills essential for use of microprocessors in data acquisition, control, and instrumentation systems. Analog and digital signal conditioning, communication, and processing. A/D and D/A converters for microprocessors. RS232 and other communication standards. Laboratory study and evaluation of microcomputer system; design and implementation of interfacing projects. Prerequisites: (EENG281 or EENG282 or PHGN215) and EENG284 or PHGN317. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG385. ELECTRONIC DEVICES AND CIRCUITS. 4.0 Semester Hrs.
Equivalent with EGGN385,
(I, II) Semiconductor materials and characteristics, junction diode operation, bipolar junction transistors, field effect transistors, biasing techniques, four layer devices, amplifier and power supply design, laboratory study of semiconductor circuit characteristics. Prerequisite: EENG307. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG386. FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS. 3.0 Semester Hrs.
Equivalent with EGGN386,
(I, II) This course provides an introduction to electromagnetic theory as applied to electrical engineering problems in wireless communications, transmission lines, and high-frequency circuit design. The theory and applications are based on Maxwell's equations, which describe the electric and magnetic force-fields, the interplay between them, and how they transport energy. Matlab and PSPICE will be used in homework assignments, to perform simulations of electromagnetic interference, electromagnetic energy propagation along transmission lines on printed circuit boards, and antenna radiation patterns. Prerequisites: EENG281 (C- or better) or EENG282 (C- or better), and MATH225. 3 hours lecture; 3 semester hours.

EENG389. FUNDAMENTALS OF ELECTRIC MACHINERY. 4.0 Semester Hrs.
Equivalent with EGGN389,
(I, II) 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.

EENG390. ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID. 3.0 Semester Hrs.
(I, II) Fundamentals and primary sources of energy; Energy conversion; Comprehensive energy picture in USA and the world; Generation of electric power today; Understanding of the electric power grid and how it works; Renewable energy resources and distributed generation; Wind and PV power generation; Future trend in electricly delivery; Energy sustainability. Prerequisites: EENG281 or EENG282 or PHGN215. 3 hours lecture; 3 semester hours.

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.

EENG398. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0 Semester Hrs.
(I, II) 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.

EENG399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) 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. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG411. DIGITAL SIGNAL PROCESSING. 3.0 Semester Hrs.
Equivalent with EGGN481,
(II) 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.

EENG413. ANALOG AND DIGITAL COMMUNICATION SYSTEMS. 4.0 Semester Hrs.
Equivalent with EGGN483,
(I, II) Signal classification; Fourier transform; filtering; sampling; signal representation; modulation; demodulation; applications to broadcast, data transmission, and instrumentation. Prerequisite: EENG310. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG414. ANALOG AND DIGITAL COMMUNICATION SYSTEMS. 4.0 Semester Hrs.
Equivalent with EGGN483,
(I, II) Signal classification; Fourier transform; filtering; sampling; signal representation; modulation; demodulation; applications to broadcast, data transmission, and instrumentation. Prerequisite: EENG310. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG415. MODERN CONTROL DESIGN. 3.0 Semester Hrs.
Equivalent with EGGN417,
(I, II) 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. Computer-based methods for control system design are presented. Prerequisite: EENG307. 3 lecture hours, 3 semester hours.

EENG421. SEMICONDUCTOR DEVICE PHYSICS AND DESIGN. 3.0 Semester Hrs.
(I) 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.
EENG423. INTRODUCTION TO VLSI DESIGN. 3.0 Semester Hrs.  

(I) 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 fabrication 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.

EENG425. INTRODUCTION TO ANTENNAS. 3.0 Semester Hrs.  

(I) 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.

EENG427. WIRELESS COMMUNICATIONS. 3.0 Semester Hrs.  

(I, II, S) 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. Prerequisites: EENG311 or MATH201 and EENG310. 3 hours lecture; 3 semester hours.

EENG428. COMPUTATIONAL ELECTROMAGNETICS. 3.0 Semester Hrs.  

(I) This course provides the basic formulation and numerical solution for static electric problems based on Laplace, Poisson and wave equations and for full wave electromagnetic problems based on Maxwell's equations. Variation principles methods, including the finite-element method and method of moments will be introduced. Field to circuit conversion will be discussed via the transmission line method. Numerical approximations based on the finite difference and finite difference frequency domain techniques will also be developed for solving practical problems. Prerequisite: EENG386. 3 hours lecture; 3 semester hours.

EENG429. ACTIVE RF & MICROWAVE DEVICES. 3.0 Semester Hrs.  

(II) 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. Prerequisites: EENG385. 3 hours lecture; 3 semester hours.

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

(I) 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.

EENG437. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.  

(I) 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. Prerequisites: MATH201 or EENG311, MATH332, CSCI261, Senior level standing. 3 hours lecture; 3 semester hours.

EENG450. SYSTEMS EXPLORATION AND ENGINEERING DESIGN LAB. 1.0 Semester Hr.  

(I, II) 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, with students focusing on either embedded systems or control systems. Prerequisites: EENG383 and EENG307. 3 hours lab; 1 semester hour.

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

Equivalent with EGGN485, (I) 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. Prerequisite: EENG282. 3 hours lecture; 3 semester hours.

EENG472. PRACTICAL DESIGN OF SMALL RENEWABLE ENERGY SYSTEMS. 3.0 Semester Hrs.  

Equivalent with EGGN486, (Taught on Demand) This course provides the fundamentals to understand and analyze renewable energy powered electric circuits. It covers practical topics related to the design of alternative energy based systems. It is assumed the students will have some basic and broad knowledge of the principles of electrical machines, thermodynamics, electronics, and fundamentals of electric power systems. One of the main objectives of this course is to focus on the interdisciplinary aspects of integration of the alternative sources of energy, including hydropower, wind power, photovoltaic, and energy storage for those systems. Power electronic systems will be discussed and how those electronic systems can be used for stand-alone and grid-connected electrical energy applications. Prerequisite: EENG383. 3 hours lecture; 3 semester hours.

EENG480. POWER SYSTEMS ANALYSIS. 3.0 Semester Hrs.  

Equivalent with EGGN484, (I) 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.
EENG481. ANALYSIS AND DESIGN OF ADVANCED ENERGY SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGN487,
(II) The course investigates the design, operation and analysis of complex interconnected electric power grids, the basis of our electric power infrastructure. Evaluating the system operation, planning for the future expansion under deregulation and restructuring, ensuring system reliability, maintaining security, and developing systems that are safe to operate has become increasingly more difficult. Because of the complexity of the problems encountered, analysis and design procedures rely on the use of sophisticated power system simulation computer programs. The course features some commonly used commercial software packages. Prerequisites: EENG480. 2 Lecture Hours, 3 Laboratory Hours, 3 Semester Hours.

EENG486. ELECTROMAGNETIC FIELDS AND WAVES. 3.0 Semester Hrs.
(I) 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. Prerequisite: EENG386. 3 hours lecture; 3 semester hours.

EENG489. COMPUTATIONAL METHODS IN ENERGY SYSTEMS AND POWER ELECTRONICS. 3.0 Semester Hrs.
(II) The course presents a unified approach for understanding and applying computational methods, computer-aided analysis and design of electric power systems. Applications will range from power electronics to power systems, power quality, and renewable energy. Focus will be on how these seemingly diverse applications all fit within the smart-grid paradigm. This course builds on background knowledge of electric circuits, control of dc/dc converters and inverters, energy conversion and power electronics by preparing students in applying the computational methods for multi-domain simulation of energy systems and power electronics engineering problems. Prerequisites: EENG282 or EENG382. 1 hour lecture, 2 lab hours, 3 semester hours.

EENG495. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
(I, II) 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.

EENG498. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.
(I, II) 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.
(I, II) 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. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.