ELECTRICAL ENGINEERING (EENG)

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.
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.
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. 4.0 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. May not also receive credit for EENG281. 3 hours lecture; 3 hours lab; 4 semester hours. 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.

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.
(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. 0.5-6 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.

EENG299. INDEPENDENT STUDY. 0.5-6 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.

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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 or PHGN215 (C- or better), MATH225 or MATH235. Co-requisite: EENG 391.
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. 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.
(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 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 EGGN340, 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.

EENG350. SYSTEMS EXPLORATION AND ENGINEERING DESIGN LAB. 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-Savartlaw, 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. FE ON COMPUTATIONAL METHODS FOR ELECTRICAL ENGINEERING. 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 or PHGN215 (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.

EENG392. FE ON INFORMATION AND SYSTEMS SCIENCES. 1.0 Semester Hr.

The course will present hardware and software solutions for the purpose of creating customized instrumentation and control systems. Concepts presented include 1) User Interface Design: controls, indicators, dialogs, graphs, charts, tab controls, user interface best practices 2) Software Development: basic software architecture, loops, arrays, binary logic, mathematics, data management 3) Instrumentation basics: connecting sensors to hardware, acquiring data, analyzing instrumentation accuracy, examining resolution and noise characteristics of a signal 4) Control basics: create pulse-width modulated (PWM) signals for controlling motors, servos, amplifiers, and heaters. Create a PID control algorithm to control a dynamic system. 1 hour lecture; 2 hours lab; 1 semester hour. Prerequisite: EENG281 or EENG282 and CSCI261 or CSCI200. Co-requisite: EENG307.

Course Learning Outcomes

- Students will be able to write and present a report that describes a contemporary product or process and how signal processing, control and/or instrumentation enables this product or process.
- Students will be able to utilize documentation and web resources develop signal processing, control and instrumentation applications using state of the art software and hardware
- Students will be able to describe the societal impact of current signal processing, control, instrumentation, and robotics applications.

EENG393. FE ON INTEGRATED CIRCUITS AND ELECTRONICS PRACTICUM. 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. FE ON ANTENNAS AND WIRELESS COMMUNICATIONS. 1.0 Semester Hr.

(I) 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

- 1. 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.

(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.

EENG398. SPECIAL TOPICS. 0-6 Semester Hr.

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.

EENG399. INDEPENDENT STUDY. 1-6 Semester Hr.

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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 opration 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.
(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. 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.
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.

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.

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.

(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.

EENG498. SPECIAL TOPICS. 0-6 Semester Hr.

EENG498. SPECIAL TOPICS. 1-6 Semester Hr.

EENG498. SPECIAL TOPICS. 1-6 Semester Hr.

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.

Course Learning Outcomes

EENG499. INDEPENDENT STUDY. 1-6 Semester Hr.

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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.

EENG500. ELECTRICAL ENGINEERING SEMINAR. 0.0 Semester Hrs.

This zero-credit graduate course builds on the EE department seminars in the colloquium series, which consist of presentations delivered by external or internal invited speakers on topics broadly related to electrical engineering. The seminar is mandatory for all graduate students (MS and Ph.D.). The students would need to enroll in the course every semester. Any student who cannot take the course for valid reasons should notify their adviser, who will then make a request to the EE graduate committee for a waiver. These requests could be for the duration of one semester or longer. The course will be graded as PRG/PRU based on student attendance at the department seminars in the colloquium series - the student has to attend at least two thirds of all the seminars each semester in order to get a PRG grade.

Course Learning Outcomes

- Graduates will demonstrate the ability to conduct directed research.
- Graduates will demonstrate oral and written communication skills.

EENG507. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.

Equivalent with CSCI507,CSCI512,EENG512,

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.

Course Learning Outcomes

- 1. Be able to analyze and predict the behavior of image formation, transformation, and recognition algorithms.
- 2. Be able to design, develop, and evaluate algorithms for specific applications.
- 3. Be able to use software tools to implement computer vision algorithms.
- 4. Communicate (in oral and written form) methods and results to a technical audience.

EENG509. SPARSE SIGNAL PROCESSING. 3.0 Semester Hrs.

This course presents a mathematical tour of sparse signal representations and their applications in modern signal processing. The classical Fourier transform and traditional digital signal processing techniques are extended to enable various types of computational harmonic analysis. Topics covered include time-frequency and wavelet analysis, filter banks, nonlinear approximation of functions, compression, inverse problems, compressive sensing, and connections with machine learning. Offered Spring semester of even years. Prerequisites: EENG411 and EENG515 or instructor consent.

Course Learning Outcomes

- Students will develop the link between the Fourier, time-frequency, and wavelet transforms.
- Compute and analyze linear and nonlinear approximations of functions.
- Students will be able to use sparse signal representations for solving signal restoration and inverse problems.

EENG510. ADVANCED DIGITAL SIGNAL PROCESSING. 3.0 Semester Hrs.

Equivalent with CSCI510,EGGN510,

This course covers 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. Deterministic and random signal and noise models are discussed, as are methods for noise removal and power spectrum estimation. Additional topics include multi-rate signal processing and spectral analysis using the discrete Fourier transform. 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, EENG 311, EENG 391; or consent of instructor.
Course Learning Outcomes

- Design digital filters to particular specifications (passband, cutoff, order, etc.)
- Use digital filters to process analog signals (appreciating the roles of sampling, aliasing, digital filtering, sample rate conversion, and interpolation).
- Analyze the frequency spectrum of digital and sampled analog signals using windowing and the discrete Fourier transform (DFT).
- Estimate the power spectrum of random signals.
- Implement digital signal processing techniques in computational software.

EENG511. CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS. 3.0 Semester Hrs.
The course focuses on recognizing and solving convex optimization problems that arise in applications in various engineering fields. Covered topics include basic convex analysis, conic programming, duality theory, unconstrained optimization, and constrained optimization. The application part covers problems in signal processing, power and energy, machine learning, control and mechanical engineering, and other fields, with an emphasis on modeling and solving these problems using the CVX package. Offered Spring semester of even years. Prerequisite: EENG515 or instructor consent.
Course Learning Outcomes

- Recognize convex optimization problems that arise in applications.
- Understand the basic theory of convex optimization.
- Understand how convex optimizations are solved and solve them using various free packages.
- Use convex optimization in their research work or applications.

EENG514. 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. 3 hours lecture, 3 semester hours. Prerequisite: EENG311. Co-requisite: None.
Course Learning Outcomes

- Describe sources and types of data in modern energy and automation systems.
- Apply MATLAB® commands to analyze data and develop data analytics models.
- Apply stati sti cal analysis tools to process raw data and derive statistical inferences about it.
- Apply regression techniques to model the relationship among continuous variables.
- Divide data points into clusters based on their similarity.
- Use the attributes to data instances in order to assign them to classes.
- Design simple artificial neural networks for various prediction applications.
- Evaluate the performance of a developed data analytics model using appropriate metrics.
- Identify ethical issues related to data analytics models and develop solutions for each one.

EENG515. MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS. 3.0 Semester Hrs.
(I) An introduction to mathematical methods for modern signal processing using vector space methods. Topics include signal representation in Hilbert and Banach spaces; linear operators and the geometry of linear equations; LU, Cholesky, QR, eigen- and singular value decompositions. Applications to signal processing and linear systems are highlighted, such as least-squares estimation, spectral analysis, principal component analysis, and signal classification. Offered every Fall semester.
Course Learning Outcomes

- Determine signals and their properties as elements of finite or infinite dimensional vector spaces arising in engineering and science applications.
- Use projection methods to approximate signals when exact representations do not exist.
- Interpret linear operations on signals as linear operators over a vector space and determine range space, null space, norms, adjoints, and inverses.
- Compute optimal solutions to “Ax=y” and key decompositions arising in engineering and science applications.
- Apply eigenspace, principal component analysis, and singular value decompositions of matrix operators to the analysis and design of signals and systems.
- Prove theorems related to signals and systems concepts (Evaluate).
- Design appropriate algorithms for a signal processing and systems application.
- Create presentations of proofs and project work to convince audiences of engineers and scientists of the work’s validity.

EENG517. THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS. 3.0 Semester Hrs.
This course will introduce and study the theory and design of multivariable and nonlinear control systems. Students will learn to design multivariable controllers that are both optimal and robust, using tools such as state space and transfer matrix models, nonlinear analysis, optimal estimator and controller design, and multi-loop controller synthesis. Offered Spring semester of even years. Prerequisite: EENG417.
Course Learning Outcomes

- Define control-oriented problem statements for real-world problems.
- Model, analyze, and design controllers and estimators for single-input, single-output (SISO) and multi-input, multi-output (MIMO) systems in time and frequency domains.

- Design optimal and robust controllers and estimators for these systems.
- Model, analyze, and design controllers for nonlinear systems.
- Explain the connection between state-space and transfer function representations of systems and the effects on controller design and analysis.
- Model, analyze, and design feedback control systems using MATLAB and Simulink in both the time and frequency domains.
- Understand and apply basic educational and learning theories and tools that will enhance your lifelong learning.

EENG519. ESTIMATION THEORY AND KALMAN FILTERING. 3.0 Semester Hrs.
Estimation theory considers the extraction of useful information from raw sensor measurements in the presence of signal uncertainty. Common applications include navigation, localization and mapping, but applications can be found in all fields where measurements are used. Mathematic descriptions of random signals and the response of linear systems are presented. The discrete-time Kalman Filter is introduced, and conditions for optimality are described. Implementation issues, performance prediction, and filter divergence are discussed. Adaptive estimation and nonlinear estimation are also covered. Contemporary applications will be utilized throughout the course. Offered Spring semester of odd years. 1.5 hours lecture; 1.5 hours other; 3 semester hours.
Course Learning Outcomes

- Use Bayes' rule to calculate a statistical inference. Given a description of a stochastic process, calculate the joint and conditional probabilities for this process.
- Using the appropriate algorithm, calculate the probability distribution function for the state of a dynamic system with stochastic inputs.
- Build a model of a dynamic system that includes a probabilistic description of uncertain inputs.
- Design and implement an algorithm to estimate the internal states of a linear system with input signals that are Gaussian stochastic processes.
- Design and implement an algorithm to estimate the internal states of general systems with general stochastic inputs.

EENG521. NUMERICAL OPTIMIZATION. 3.0 Semester Hrs.
Optimization is an indispensable tool for many fields of science and engineering. This course focuses on the algorithmic aspects of optimization. Covered topics include first-order (gradient descent and its variants) and second-order methods (Newton and quasi-Newton methods) for unconstrained optimization, theory and algorithms for constrained optimization, stochastic optimization and random search, derivative-free optimization, dynamic programming and simulation-based optimization, and distributed and parallel optimization. The emphasis will be on how the algorithms work, why they work, how to implement them numerically, and when to use which algorithm, as well as applications in different science and engineering fields. Offered Spring semester of odd years.
Course Learning Outcomes

- Recognize different types of optimizations, their targeting application areas, and the most suitable algorithms to solve them.
- Understand the mechanisms for different numerical algorithms and the scenarios that they work best.
- Be able to implement optimization algorithms numerically and tune the hyper-parameters.
- Understand optimality conditions for constrained and unconstrained optimizations and use them to design algorithms.
- Use existing optimization packages to quickly prototype and solve optimization formulations of your problems.
- Know how to model, solve, and analyze optimization problems arising in various application fields.

EENG524. 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. Prerequisite: EENG386.
Course Learning Outcomes

- Learn how to work with differential and integral forms of Maxwell’s equations and plane electromagnetic waves and use them to design electromagnetic devices
- 2. Learn how to build electromagnetic models and use them to solve electromagnetic problems
- 3. Learn how to develop computer programs to visualize electromagnetic fields such as waveguide modes or signal propagation on transmission lines

EENG525. ANTENNAS. 3.0 Semester Hrs.
This course provides an in depth introduction to the analysis and synthesis of antennas and antenna arrays. Students are expected to use MATLAB to model antennas and their performance. An extensive final project that involves experimental or computer demonstrations is required. EENG525 has more depth and required work than EENG425. EENG525 students will have one additional problem for each homework assignment, one additional problem on exam, more difficult paper to review and present, and higher expectations on antenna and direction finding projects. Offered every Spring semester. Prerequisite: EGGN386 or GPGN302 or PHGN384.
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.
- Design, build, and test an antenna array (for students in EENG525).

EENG526. ADVANCED ELECTROMAGNETICS. 3.0 Semester Hrs.
In this course the fundamental theorems of electromagnetics are developed rigorously. Wave solutions are developed in Cartesian, cylindrical, and spherical coordinate systems for bounded and unbounded regions.

Course Learning Outcomes

- Develop a good understanding of time harmonic electromagnetic waves.
- Develop a good understanding of electromagnetic theorems and principles.
- Develop and analyze the wave equation solution in different coordinate systems.
- Apply EM boundary conditions to analyze the reflections and transmissions from layered media.
- Develop the formulation and understanding of wave propagation inside waveguides and cavities.
- Develop MATLAB programs to understand the propagation and scattering of electromagnetic waves.

EENG527. WIRELESS COMMUNICATIONS. 3.0 Semester Hrs.
Equivalent with EENG513,
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. EENG527 has more depth and required work than EENG427. EENG527 students will have one additional problem for each homework assignment, one additional problem on exam, more difficult paper to review and present, and higher expectations on final project. Offered every Spring semester. Prerequisite: EENG386, EENG311, and EENG388.
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.

EENG528. COMPUTATIONAL ELECTROMAGNETICS. 3.0 Semester Hrs.
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. Offered every Fall semester.
Course Learning Outcomes

- Learn how to develop MATLAB programs 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.

EENG529. 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. Offered every Spring semester. Prerequisite: EENG385 and EENG430 or EENG530.
Course Learning Outcomes

- Analyze the fundamental system aspects of modern communication and radar systems, comparing and contrasting their key features and functionalities.
- Evaluate the effectiveness of various hardware components used, justifying your selection based on specific design criteria.
- Create designs for active microwave circuits and devices, simulating and optimizing their performance using appropriate modeling techniques.
- Synthesize your knowledge of microwave circuits and devices to develop receiver and transmitter designs.

EENG530. 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. Offered every Fall semester.
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.

EENG532. LOW TEMPERATURE MICROWAVE MEASUREMENTS FOR QUANTUM ENGINEERING. 3.0 Semester Hrs.
The goal of the course is to provide hands on training in high-frequency, low-temperature measurements which are requisite for quantum information applications. This course introduces the fundamentals of high-frequency measurements, the latest techniques for accuracy-enhanced automated microwave measurements, low-temperature measurement techniques, low noise measurements, and common devices used in quantum information. The course will have three modules. The first module, basics of electronic measurements, will include chip layout, power measurements, ground loop testing, impedance measurements, noise fundamentals, cable and device fabrication and care. The second module, high frequency measurements, will include measurements of basic scattering parameters, accuracy enhancement and calibration, transmission line, amplifier, and oscillator characterization including noise measurements. The third module, low-temperature measurements, will cover critical parameters for superconductors and Josephson junctions, measurements of superconducting resonators, characterization of low-temperature electronic elements including amplifiers. At the end of this course the students will know how to use network analyzers, spectrum analyzers, cryostats, the software Eagle for chip design, amplifiers, and filters. Offered every Fall semester.
Course Learning Outcomes

- 1. Describe key RF, wireless and microwave measurement parameters
- 2. Understand how to use a range of RF, wireless and microwave test equipment
- 3. Reduce the risk of expensive test equipment damage, repair costs and downtime
- 4. Understand how to correctly perform common RF and microwave measurements
- 5. Understand the basics of low-temperature measurements including critical parameters for superconductors and Josephson junctions, as well as characterization of low-temperature electronic elements
- 6. Better utilize test and measurement equipment features and functionality
- 7. Develop improved problem solving capability due to better understanding

EENG533. 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. Offered every Spring semester. Prerequisites: 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
- Understand the basic operation mechanism of transmitters and receivers in communication systems
- Gain a basic understanding on how vector network analyzers operate and how to measure active microwave devices
- Learn how to model active microwave circuits and devices using a professional CAD tool.

EENG536. PHASED & ADAPTIVE ARRAYS. 3.0 Semester Hrs.
This course introduces the basic fundamentals of phased arrays and adaptive antenna arrays with a focus on array processing. The topics that will be introduced are antenna array fundamentals and radiation analysis techniques, elements for antenna arrays, linear, planar, and non-planar arrays, focused arrays, radiation pattern synthesis, phased array and adaptive array system architectures, phase-delay and time-delay systems, analog and digital beamforming, adaptive nulling algorithms and interference cancellation, and angle of arrival estimation algorithms. This foundational knowledge will then be used by the students to conduct a comprehensive course project on a special topic in this area.
Course Learning Outcomes

- Learn fundamentals of antenna arrays in linear, planar, and non-planar configurations.
- Learn electronically scanned array operations and characteristics.
- Design, analyze, and characterize the performance of antenna array.
- Learn techniques for array coupling manipulation.
- Develop and design phased array beamforming systems.

EENG540. INTRODUCTION TO RADAR SYSTEMS. 3.0 Semester Hrs.
This course provides an introduction to radar system engineering, it covers the fundamental concepts needed to understand the design and operation of modern radar systems for a variety of applications. Topics covered include the radar equation, radar cross section, radar clutter, detection and receiver design, transmitters and antenna systems. Applications include pulsed, continuous-wave, and frequency-modulated radars, Doppler radar, and synthetic aperture radar. Demonstrations will be conducted to complement the theoretical analysis.
Course Learning Outcomes

- Understand the basic concepts, operation, and techniques necessary to analyze and access the performance of modern radar systems.
- Learn the components of a radar system and their relationship to overall system performance and to be able to specify the subsystem performance requirements in a radar system design.
- Develop computer programs to analyze and visualize radar signals, phased array patterns, and RSC of targets.

EENG570. ADVANCED HIGH POWER ELECTRONICS. 3.0 Semester Hrs.
Basic principles of analysis and design of circuits utilizing high power electronics. AC/DC, DC/AC, AC/AC, and DC/DC conversion techniques. Laboratory project comprising simulation and construction of a power electronics circuit. Offered Fall semester of even years. Prerequisites: EENG470 or instructor consent.

Course Learning Outcomes

- Define power electronics and recognize power electronics devices, circuits, and applications.
- Classify converter types and conversion functions, typical of high-voltage and high-power applications.
- Recognize converter topologies, derive their governing equations, and design, analyse and simulate converter circuits.
- Analyze multilevel converters, their operation and control, and comparison with 2-level converters.
- Analyze modular multilevel converters, their design, control, and application.

EENG572. RENEWABLE ENERGY AND DISTRIBUTED GENERATION. 3.0 Semester Hrs.

A comprehensive electrical engineering approach on the integration of alternative sources of energy. One of the main objectives of this course is to focus on the inter-disciplinary aspects of integration of the alternative sources of energy which will include most common and also promising types of alternative primary energy: hydropower, wind power, photovoltaic, fuel cells and energy storage with the integration to the electric grid.

Course Learning Outcomes

- Understand the fundamentals of renewable energy and distributed energy systems.
- Model renewable and distributed energy systems using EMT and dynamic simulation tools.
- Analyze the integration of renewable and distributed energy systems into power grids.
- Conduct system-level case studies with simulation tools.
- Design and evaluate solutions for the seamless integration of renewable and distributed energy systems into power systems.

EENG573. ELECTRIC POWER QUALITY. 3.0 Semester Hrs.

Electric power quality (PQ) deals with problems exhibited by voltage, current and frequency that typically impact end-users (customers) of an electric power system. This course is designed to familiarize the concepts of voltage sags, harmonics, momentary disruptions, and waveform distortions arising from various sources in the system. A theoretical and mathematical basis for various indices, standards, models, analyses techniques, and good design procedures will be presented. Additionally, sources of power quality problems and some remedies for improvement will be discussed. The course bridges topics between power systems and power electronics. Offered Spring semester of even years. Prerequisites:EENG480 and EENG470 or instructor consent.

Course Learning Outcomes

- Identify the sources of harmonics and describe how they impact the distribution system
- Propose solutions for mitigating the effects of harmonics in a distribution system
- Determine the root-causes of short-duration voltage variations in distribution grids
- Analyze the causes and effects of long-duration voltage variations in a distribution system
- Propose mitigating solutions for short and long-duration voltage variations
- Identify the sources of transients in distribution systems and propose mitigation techniques
- Simulate various power quality events using engineering software

EENG577. ADVANCED ELECTRICAL MACHINE DYNAMICS FOR SMART-GRID SYSTEMS. 3.0 Semester Hrs.

This course provides engineering science analysis and focuses on the application of the abc frame of reference to develop state space and equivalent network models for electric machines and drive systems. The course focuses primarily on the modeling and dynamic performance prediction of electric machines and associated power electronic in smart grids and renewable energy systems/subsystems. The developed models will be used in computer simulations for the characterization and performance prediction of synchronous and induction machines, permanent magnet synchronous machines synchronous reluctance and switched reluctance machines, as well as other advanced machine systems, such as axil flux generators and Linear PM machines. Offered Spring semester of odd years. Prerequisites: EENG389 and EENG470.

Course Learning Outcomes

- Explain power calculations, magnetic fields/circuits/material, and power/torque relationships of energy conversion devices.
- Explain principle of operation of selected energy conversion devices used in smart grid applications.
- Write and explain a device state space model and illustrate, label, and describe a device equivalent circuit model and relate its parameters and terminal inputs/outputs to those of an actual device.
- Use state space models/equivalent circuits to predict and analyze device external operational characteristics (current, voltage, power, energy, torque, speed, losses, efficiency, etc.).
- Compute the energy conversion device model parameters (reactance and resistance) and/or initial conditions (current, voltage, power, torque, speed, losses) and implement utilizing a computer tool (MATLAB/SIMULINK).
- Develop and design a system/sub-system with an energy conversion device. Implement the state space model/equivalent circuit with MATLAB and/or SIMULINK to predict, analyze, and critique the external performance characteristics (current, voltage, power, energy, torque, speed, losses, efficiency, etc.).
- Prepare and write in groups of 2/3 students an IEEE formatted paper to explain, analyze, and critique a case study from one of the modules of weeks 3-7. Present in poster format at the course Final Project: Online Mini-Conference.

EENG580. POWER DISTRIBUTION SYSTEMS ENGINEERING. 3.0 Semester Hrs.

This course deals with the theory and applications of problems and solutions as related to electric power distribution systems engineering from both ends: end-users like large industrial plants and electric utility companies. The primary focus of this course in on the medium voltage (4.16 kV ? 69 kV) power systems. Some references will be made to the LV power system. The course includes per-unit methods of calculations; voltage drop and voltage regulation; power factor improvement and shunt compensation; short circuit calculations; theory and fundamentals of symmetrical components; unsymmetrical faults; overhead distribution lines and power cables; basics and fundamentals of distribution protection. Offered in fall semester of odd years. Prerequisites: EENG480 or instructor consent.

Course Learning Outcomes

- Comprehend the fundamentals of distribution systems engineering.
- Create and analyze distribution system models.
- Analyze distribution load flow for different scenarios.
- Analyze voltage regulation in distribution systems.
- Comprehend recent advances in distribution automation.
- Apply computational simulation tools to analyze distribution systems.

EENG581. POWER SYSTEM OPERATION AND MANAGEMENT. 3.0 Semester Hrs.

This course presents a comprehensive exposition of the theory, methods, and algorithms for Energy Management Systems (EMS) in the power grid. It will focus on (1) modeling of power systems and generation units, (2) methods for dispatching generating resources, (3) methods for accurately estimating the state of the system, (4) methods for assessing the security of the power system, and (5) an overview of the market operations in the grid. Offered Fall semester of even years. Prerequisite: EENG480 or instructor consent.

Course Learning Outcomes

- Describe the principles of power generation using renewable and non-renewable energy resources
- Explain root causes of global warming and propose mitigation strategies related to power generation
- Identify ethical issues with energy systems related to the society and the environment
- Design controllers for regulating the voltage and frequency of a synchronous generator
- Apply Newton-Raphson and fast decoupled techniques to solve the power flow problem
- Apply the weighted least squares method to estimate the states of a power system
- Use time-series analysis to forecast the power demand in a distribution system
- Formulate a constrained optimization problem to optimally dispatch generation units in a power grid

EENG582. HIGH VOLTAGE DC (HVDC) SYSTEMS. 3.0 Semester Hrs.

This course deals with the theory, modeling and applications of HV and EHV power transmission systems engineering. The primary focus is on overhead AC transmission line and voltage ranges between 115 kV to 500 kV. HVDC and underground transmission will also be discussed. The details include the calculations of line parameters (RLC); steady-state performance evaluation (voltage drop and regulation, losses and efficiency) of short, medium and long lines; reactive power compensation; FACTS devices; insulation coordination; corona; insulators; sag-tension calculations; EMTP, traveling wave and transients; fundamentals of transmission line design; HV and EHV power cables: solid dielectric, oil-filled and gas-filled; Fundamentals of DC transmission systems including converter and filter.

Course Learning Outcomes

- Understand HVDC Fundamentals: Learn the core principles, components, and operating mechanisms that di#erentiate HVDC systems from traditional AC systems.
- Explore various HVDC system con#gurations, including back-to-back, point-to-point, and multi-terminal designs, and understand their speci#c applications and technical requirements.
- Design and analyze modular multilevel converter technologies.
- Examine the role of line-commutated and voltage-source converters, their functionalities, and the latest advancements in converter technology.
- Develop knowledge of control methods and protection schemes that ensure the reliable, safe operation of HVDC systems.
- Analyze how HVDC systems facilitate renewable energy integration, long-distance power transfer, and the stability of modern power grids.

EENG584. POWER SYSTEM RISK MANAGEMENT. 3.0 Semester Hrs.

This course presents a comprehensive exposition of the theory, methods, and algorithms for risk management in the power grid. The course will focus on: (1) power system stability analysis (steady state, dynamic, and transient), (2) analysis of internal and external threats to power systems, e.g. component failures, faults, natural hazards, cyber intrusions, (3) introduction to power system security assessment, (4) fundamentals of modeling risk, vulnerability assessment and loss calculations, (5) mitigating techniques before, during and after the course of major events and disturbances. Offered Spring semester of odd years. Prerequisites: EENG480 and EENG481.

Course Learning Outcomes

- Identify elements of social vulnerability related to large-scale power outages.
- Define and quantify risk for different engineering applications.
- Assess the stability of a power system in the sense of frequency, rotor angle, and voltage.
- Identify internal or external hazards threatening the stability and security of the power grid.
- Propose solutions for grid resilience before, during and in the aftermath of disturbances.
- Predict the probability and severity of internal or external hazards to power systems.
- Apply MATLAB/Simulink® or PSCAD® to study the dynamics of power systems.

EENG585. AI FOR POWER AND RENEWABLE ENERGY SYSTEMS. 3.0 Semester Hrs.

AI is transforming power and energy systems. This course will help students understand and use AI methods and tools and apply them to forecast, analyze, and control power and renewable energy systems. The course starts with an introduction to the mainstream AI tools as well as basic Python programming. Then, the course covers the basics of AI/Machine learning and how to train and test machine learning models. The core of the course will focus on various AI applications in power and renewable energy systems. It provides students many hands-on opportunities to work on real-world-inspired problems. Prerequisite: EENG480.

Course Learning Outcomes

EENG586. COMMUNICATION NETWORKS FOR POWER SYSTEMS. 3.0 Semester Hrs.

Advanced topics on communication networks for power systems including the fundamentals of communication engineering and signal modulation/transfer, physical layer for data transfer (e.g., wireline, wireless, fiber optics), different communication topologies for power networks (e.g., client-server, peer-to-peer), fundamentals of SCADA system, data modeling and communication services for power system applications, common protocols for utility and substation automation, and cyber-security in power networks. Offered Fall semester of odd years. Prerequisite: EENG480 or instructor consent.

Course Learning Outcomes

- List the different layers of the TCP/IP network architecture and explain the role of each one.
- Identify and justify the desired quality-of-service for a given data communication flow between two given components in a power system.
- Choose the appropriate communication media for various telecommunication applications.
- Choose the appropriate parameters for various layers of the TCP/IP network architecture.
- Identify, compare, design, and implement appropriate communication technologies for a given power system.
- Design a communication architecture for a given power system.
- List the common cyber-security threats to a given power system and propose industry-practice countermeasures for each one.

EENG587. POWER SYSTEMS PROTECTION AND RELAYING. 3.0 Semester Hrs.

Theory and practice of power system protection and relaying; Study of power system faults and symmetrical components; Fundamental principles and tools for system modeling and analysis pertaining to relaying, and industry practices in the protection of lines, transformers, generators, motors, and industrial power systems; Introduction to microprocessor based relaying, control, and SCADA.

Course Learning Outcomes

- Describe the principles and advantages of using symmetrical components for fault analysis.
- Analyze power system unbalanced faults using symmetrical components and convert the results from the sequence domain back to the phase domain.
- Design overcurrent protection for simple feeders using IEEE standard curves and overcurrent protection coordination principles.
- Understand the basic principles of distance protection.
- Model and configure distance protection relays using commercial tool.
- Understand the impact of inverter-based devices on power system fault analysis and protection.

EENG588. POWER SYSTEM ECONOMICS AND ELECTRICITY MARKETS. 3.0 Semester Hrs.

This course aims to provide a comprehensive overview of power system economics and electricity market structures and operations. Students will be equipped with essential tools and skills sought by key stakeholders in the electric power sector, enabling them to properly formulate and solve optimization problems in power system economics, calculate and evaluate locational marginal prices, and analyze different market frameworks and ancillary services while considering future opportunities and challenges. The course content aligns with major energy industry trends, such as decarbonization, digitalization, and decentralization, preparing students to drive advancements in power system efficiency, affordability, and sustainability. In doing so, it supports engineers in advancing their careers in the energy sector and contributes meaningfully to the power industry's transformation. Prerequisites: EENG480 or instructor consent.

Course Learning Outcomes

- Distinguish different electricity market frameworks (i.e., market structures, trading mechanisms, and regulatory mechanisms) at both wholesale and retail level.
- Formulate market clearing, economic dispatch, and unit commitment problems using deterministic and stochastic mathematical optimization models.
- Determine locational marginal prices considering generation and transmission constraints.
- Solve convex optimization problems in power system economics using computational tools.
- Distinguish different types of ancillary services and their procurement processes in different jurisdictions.
- Assess the impact of extreme events on wholesale electricity prices using real-world data.
- Analyze opportunities, challenges, and needs in existing electricity markets to support increased decarbonization, digitalization, and decentralization in the power sector.

EENG589. DESIGN AND CONTROL OF WIND ENERGY SYSTEMS. 3.0 Semester Hrs.

Wind energy provides a clean, renewable source for electricity generation. Wind turbines provide electricity at or near the cost of traditional fossil-fuel fired power plants at suitable locations, and the wind industry is growing rapidly as a result. Engineering R&D can still help to reduce the cost of energy from wind, improve the reliability of wind turbines and wind farms, and help to improve acceptance of wind energy in the public and political arenas. This course will provide an overview of the design and control of wind energy systems. Offered Spring semester of odd years. Prerequisite: EENG307.

Course Learning Outcomes

- Evaluate the benefits and drawbacks of wind energy and its role in a sustainable energy future.
- Organize wind energy systems around their major subsystems, including but not limited to the wind resource, rotor aerodynamics, turbine mechanical dynamics, electrical systems of the turbine and utility interconnection, control system, and broader contexts in which these systems are located.
- Design a controller for a wind energy system under time-varying wind input conditions, model this controller using available software, and evaluate its benefits and drawbacks.
- Develop and then conduct a research project for specific wind energy application.
- Improve your student- and self-driven learning skills.

EENG597. SUMMER PROGRAMS. 0-6 Semester Hr.

EENG598. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 0-6 Semester Hr.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EENG598. SPECIAL TOPICS. 0-6 Semester Hr.

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EENG598. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 0-6 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EENG599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EENG599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

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EENG600. GRADUATE SEMINAR ON SMART-GRID ELECTRICAL POWER AND ENERGY SYSTEMS. 3.0 Semester Hrs.
(I, II, S) In this course, learners will plan, develop, and present a research project in their field of technology on a subject related to Smart-Grid, Electrical Power, and Energy Systems. Their chosen topic and seminar must demonstrate their knowledge and skills in scientific and engineering analysis and modeling, project handling, technical writing, problem-solving, evaluation and assessment of their goals, and oral presentation techniques. Learners will advance their research training in the design of future electric power grids, conduct analysis, simulation and data evaluation of electricity infrastructure in the area of Smart Cities, prosumers and distributed generation and will attend and make seminar or another modern presentation on cutting-edge issues of enhanced livability, enhanced workability, and increased sustainability for Transportation and Electrification, Power System Resiliency, Energy Economy, Community Micro-grids, Data Analytics, and Renewable Energy. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Advance their research training in the design of future electric power grids with high penetration of renewable energy and electrical energy storage
- Conduct analysis, simulation and data evaluation of electricity infrastructure in the area of Smart Cities, prosumers and distributed generation
- Prepare and make a seminar presentation in a very dynamic and modern format on cutting edge issues of enhanced livability, enhanced workability, and enhanced sustainability for Transportation and Electrification, Power System Resiliency, Energy Economy, Community, Micro-grids, Data Analytics, and Renewable Energy
- Communicate (in oral and written formats) results to a both a technical as well as a non-technical audience

EENG617. INTELLIGENT CONTROL SYSTEMS. 3.0 Semester Hrs.
Fundamental issues related to the design on intelligent control systems are described. Neural networks analysis for engi neering systems are presented. Neural-based learning, estimation, and identification of dynamical systems are described. Qualitative control system analysis using fuzzy logic is presented. Fuzzy mathematics design of rule-based control, and integrated human-machine intelligent control systems are covered. Real-life problems from different engineering systems are analyzed. Prerequisite: EENG517. 3 hours lecture; 3 semester hours. Taught on demand.

EENG618. NONLINEAR AND ADAPTIVE CONTROL. 3.0 Semester Hrs.
This course presents a comprehensive exposition of the theory of nonlinear dynamical systems and the applications of this theory to adaptive control. It will focus on (1) methods of characterizing and understanding the behavior of systems that can be described by nonlinear ordinary differential equations, (2) methods for designing controllers for such systems, (3) an introduction to the topic of system identification, and (4) study of the primary techniques in adaptive control, including model-reference adaptive control and model predictive control. Offered on demand. Prerequisite: EENG517.

EENG683. COMPUTER METHODS IN ELECTRIC POWER SYSTEMS. 3.0 Semester Hrs.
This course deals with the computer methods and numerical solution techniques applied to large scale power systems. Primary focus includes load flow, short circuit, voltage stability and transient stability studies and contingency analysis. The details include the modeling of various devices like transformer, transmission lines, FACTS devices, and synchronous machines. Numerical techniques include solving a large set of linear or non-linear algebraic equations, and solving a large set of differential equations. A number of simple case studies (as per IEEE standard models) will be performed. Prerequisites: EENG580 and EENG582 or equivalent; a strong knowledge of digital simulation techniques. 3 lecture hours; 3 semester hours. Taught on demand.

EENG698. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 0-6 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EENG699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, 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: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EENG707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.