Electrical and Computer Engineering

The School of Electrical and Computer Engineering is highly recognized throughout the nation for its student-centered, laboratory intensive curriculum. It is a partner of choice for employers seeking well-educated, highly-motivated and uniquely creative college graduates dedicated to life-long learning. The School has devoted professors from prestigious universities who serve, instruct and mentor undergraduate and graduate students pursuing Bachelor of Science (BS), Master of Engineering (MEng), Master of Science (MS), or Doctorate (PhD) degrees in electrical engineering or a BS degree in computer engineering. Both the undergraduate Electrical Engineering and Computer Engineering programs are accredited by ABET—the leading accreditor of engineering programs—to assure students, parents, industry partners and other stakeholders that our programs are of the highest quality.

Electrical engineers and computer engineers have been at the center of the technological revolution that has occurred over the past 100 years. Marvels such as the transistor, radio, telephone, television, internet, microprocessor, computer, tablet, radar system, motor, wind generator, GPS, smart phone, laser, microwave oven, electric car, pacemaker, antennas and the flat panel display, to name only a handful, have resulted from the hard work and creative talents of electrical engineers and computer engineers. And since electricity and computers are essential in a modern society, the electrical engineer and the computer engineer will always be in high demand.

Electrical engineering encompasses many exciting subdisciplines including energy systems, machines, power electronics, analog electronics, digital electronics, mixed-signal electronics, VLSI chips, instrumentation, sensors, signal processing, machine vision, artificial intelligence, communications, control systems, robotics, wireless devices, electromagnetic fields, photonics, embedded controllers, networking, software development, biomedical devices and computer architecture. The School encompasses all of these subdisciplines in its curriculum or research activities.

Computer Engineering is a relatively young engineering discipline that combines a strong foundation in electrical engineering with elements of computer science, including hardware and software integration, and design. Computer engineering includes digital logic design, computer architecture, digital data communications, computer and sensor interfacing, microprocessors, digital control, VLSI circuits and systems, operating and software systems, and computer arithmetic.

Beyond creating technology, electrical and computer engineers of tomorrow must be aware of the social, economic, ethical and environmental impact of their respective technologies. They must also communicate effectively, possess excellent teamwork skills, and understand, perform and complete the process of engineering design. The undergraduate programs in electrical engineering and computer engineering at Oklahoma State University equip graduates with these critical skills.

Undergraduate Program Educational Objectives

The Undergraduate Program Educational Objectives reflect the aspirational expectations for our electrical engineering and computer engineering graduates after they enter their professional careers. Specifically:

- Our Graduates will be widely employed across the range of subdisciplines within electrical engineering and computer engineering, and will be highly sought after by industrial, academic, non-profit and governmental organizations.
- Our Graduates will compete in a technologically changing world, collaborate in a diverse workforce, and communicate effectively their knowledge and ideas to colleagues, employers, customers and stakeholders.
- Our Graduates will be recognized leaders, team players, problem solvers, innovators and entrepreneurs in their profession.
- Our Graduates will identify and contribute to solving grand-challenge problems that improve the lives of people in Oklahoma, the United States, and around the world, serving their communities and their profession to produce a lasting, significant and positive impact.
- Our Graduates will abide by the highest ethical standards of professional practice in a technologically changing, professional environment.
- Our Graduates will continue to develop professionally throughout their lives by being adaptive learners with a never ending desire to assimilate new knowledge and embrace new technologies.
- Our Graduates will have the knowledge to earn professional registration or certification in their field or earn an advanced post-graduate or professional degree should they choose.
- Our Graduates will make a positive difference in the world.

Undergraduate Program and Student Learning Outcomes

To support the aforementioned Program Educational Objectives, the School has established Student Learning Outcomes that are regularly assessed and expected of all students upon completion of their chosen program in Electrical Engineering or Computer Engineering. Attainment of the following outcomes prepares graduates to enter the professional practice of engineering:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science and mathematics;
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety and welfare, as well as global, cultural, social, environmental and economic factors;
3. an ability to communicate effectively with a range of audiences;
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental and societal contexts;
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks and meet objectives;
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions;
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.
The undergraduate electrical engineering and computer engineering programs at Oklahoma State University prepare each graduate for a life-long professional career. During the first two years of study, students enter into Pre-Professional School and complete a carefully designed program consisting of mathematics, physics, chemistry, statics, introductory electrical and computer engineering courses, computer science and selected courses in the humanities and social sciences. After successfully completing Pre-Professional school, students are admitted into Professional School and enroll in specific electrical engineering and/or computer engineering courses.

Electrical engineering and computer engineering students in Professional School obtain fundamental knowledge and technical skills needed by tomorrow’s professionals. For electrical engineering students, these skills are learned in one of five areas of specialization that enable students to customize course choices to gain both a breadth of knowledge and a depth of understanding in a specific chosen area. These specializations areas include a) control systems, digital signal processing, and communication systems, b) energy and power, c) computer systems and digital electronics, d) analog electronics, and e) microwaves and photonics. Computer engineering students learn these skills by focusing on their own challenging specialized curriculum, which is also designed to provide breadth and depth within the discipline. Specialized computer engineering topics include microcontrollers, embedded controllers, computer architecture, discrete mathematics, digital logic design, networking, cybersecurity, mobile computing and digital electronics.

By tailoring the program to align student interests with faculty strengths, the School enhances faculty-student interactions to ensure academic excellence. All electrical engineering and computer engineering students receive multiple engineering design experiences throughout Professional School. Instructional laboratories are a central part of the curriculum to grant opportunities for hands-on experience in areas such as microcomputers, digital logic design, electronics, networks, instrumentation, optics, real-time digital signal processing and electromagnetics.

Engineering design laboratories require students to solve open-ended problems in a manner that demonstrate the students’ ability to apply fundamental concepts, creativity and imagination, and to solve realistic problems of practical importance. These problems have several possible outcomes—students must choose an acceptable approach and demonstrate that the optimal outcome has been met.

The capstone design experience is a two-course sequence typically taken during the student's last two semesters of the program. The capstone experience gives students an opportunity to apply and demonstrate the skills that they have developed throughout the program. These design courses integrate theory analysis, simulation, design and experimental skills the students have developed during their course of study. Teamwork, communication skills, and the complete engineering design process—from problem definition to prototype that includes both presentation and documentation—are emphasized.

Student design teams receive individual project mentoring from an appropriate faculty member who provides project management and supervision. The capstone experience concludes with a formal public design demonstration, oral presentation and written report. Laboratories are available to all students in electrical engineering and computer engineering that provide state-of-the-art capabilities for designing, prototyping, testing and diagnosing advanced hardware and software systems.

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**Degree Programs and Options**

The School of Electrical and Computer Engineering (ECE) offers a full range of undergraduate and graduate program choices that allow students to excel in their careers. Specifically, the School of Electrical and Computer Engineering offers five degrees:

- **Bachelor of Science in Electrical Engineering (BSEE)**
- **Bachelor of Science in Computer Engineering (BSCpE)**
- **Master of Engineering in Electrical Engineering (MEngEE, non-thesis)**
- **Master of Science in Electrical Engineering (MSEE, thesis)**
- **Doctor of Philosophy in Electrical Engineering (PhD EE)**

**Bachelor of Science:**
- This degree program is designed to provide fundamental scientific and mathematical knowledge needed for an engineering education and an entry-level engineering career.
- Broad-based and in-depth technical knowledge is provided to understand the scope of the electrical engineering and computer engineering professions.
- The degree focuses on analysis and design methods, laboratory and simulation experiences, and theoretical and practical problems.
- Requirements: 123 credit hours (BSEE) and 124 credit hours (BSCpE).

**Master of Engineering:**
- This degree program is tailored to students who wish to gain advanced knowledge and expertise knowledge in subject areas associated with their professional pursuits.
- This non-research, non-thesis instructional program is ideal for Distance Education students or for baccalaureate graduates interested in professional development.
- This program is available online.
- Requirements: 33 credit hours of coursework. Specific requirements for the MEngEE program are available on the web in the document entitled “Memorandum to Graduate Students;” see https://ece.okstate.edu/.

**Master of Science:**
- This degree program is tailored to students who wish to gain advanced knowledge in subject areas associated with their professional pursuits.
- The program emphasizes research as part of the learning experience and culminates with the defense of a thesis.
- This program is an ideal preparatory experience for students who wish to pursue a PhD.
- This program is available online.
- Requirements: 24 credit hours of coursework and 6 credit hours of thesis research. Specific requirements for the MSEE program are available on the web in the document entitled “Memorandum to Graduate Students;” see https://ece.okstate.edu/.

**Doctor of Philosophy:**
- This degree program is tailored to students who desire to have a teaching and research career in academia or a research career in industry or government laboratories.
- This program is ideal for those students who have a passion to acquire expertise knowledge.
The program emphasizes the creation of new knowledge during the research process, the publication of that knowledge, and the defense of a dissertation.

Requirements: 73 total credit hours beyond the BSEE/BSCpE degree. Specific requirements for the PhD program are available on the web in the document entitled “Memorandum to Graduate Students;” see https://ece.okstate.edu/.

Options: Students are also given the option to combine degrees to take advantage of common courses between various degrees, thereby reducing the total number of credit hours relative to non-combining options. These combining options are highly attractive from a financial and career point of view. That is, these options are less expensive and take less time. Knowledge gained in these degree programs adds value to what the student can do once or while employed. The current combining options are:

- Dual BSEE and BSCpE degrees (136 credit hours)
- Joint “4+1” BSEE/BSCpE plus MEngEE degrees (147/148 credit hours)

With effective planning, the dual BSEE and BSCpE program can be completed in four to five years by taking approximately 16 to 17 credit hours of courses each semester. It may even take less time if students have Advanced Placement credit hours. This dual degree program allows a student to have a true comprehensive education across the electrical and computer engineering spectrum, thus preparing the student for just about any entry-level career in electrical engineering or computer engineering. The program effectively requires the completion of the BSCpE degree plus 12 additional credit hours in non-computer, electrical engineering courses. A degree advising sheet for the dual program is posted on the School’s web page: https://ece.okstate.edu/. This sheet has been devised to assure that the degree requirements for both the BSCpE and BSEE degrees are satisfied in the most expeditious manner.

The “4+1” program—available only to OSU baccalaureate students—is a five-year program that combines the BSEE or BSCpE degree with the M.Eng.EE degree. It is designed to give students a broad-based education in electrical engineering or computer engineering along with a highly in-depth education in a few key areas. This program is ideal for those students who want advanced knowledge to enhance their competitiveness in the work force and to satisfy their longing for in-depth knowledge that cannot be obtained in the baccalaureate degrees. Specific requirements for the “4+1” program are available on the web in the document entitled “Memorandum to Graduate Students;” see https://ece.okstate.edu/.

A degree in electrical engineering or computer engineering is an excellent foundation for other professional fields such as medicine and law. Many graduates also pursue advanced programs in business and management after earning a degree in engineering.

Courses

ECEN 2011 Experimental Methods I
Prerequisites: PHYS 2114; Co-requisite(s): ENSC 2613
Description: Basic electrical measurements and instrumentation techniques and devices. Use of voltmeters, ammeters, oscilloscopes, impedance bridges to study resistive, inductive, and capacitive circuit elements in steady state and transient operation. Reinforces ENSC 2613 and introduces design of instrumentation networks. Serves as introduction for non-majors. Previously offered as ECEN 3013.
Credit hours: 1
Contact hours: Lab: 2 Contact: 2
Levels: Undergraduate
Schedule types: Lab
Department/School: Elec & Computer Engr

ECEN 2714 Fundamentals of Electric Circuits
Prerequisites: Prerequisite in MATH 2153; prerequisite or concurrent enrollment in MATH 2233; prerequisite or concurrent enrollment in PHYS 2114.
Description: Circuit analysis techniques including equivalent networks and mesh/node formulation of network equations; operational amplifiers; RL, RC and RLC transient and steady-state circuit analysis; energy and power; electrical measurements and instrumentation.
Credit hours: 4
Contact hours: Lecture: 3 Lab: 2 Contact: 5
Levels: Undergraduate
Schedule types: Lab, Lecture, Combined lecture and lab
Department/School: Elec & Computer Engr

ECEN 3020 Supervised Research Project
Prerequisites: Consent of instructor and ECEN department head.
Description: Supervised research project for qualified students. May be repeated no more than three times for a total of three credit hours. Offered for variable credit, 1-3 credit hours, maximum of 3 credit hours.
Credit hours: 1
Contact hours: Contact: 1 Other: 1
Levels: Undergraduate
Schedule types: Independent Study
Department/School: Elec & Computer Engr

ECEN 3113 Energy, Environment and Economics
Prerequisites: ECEN 3714, degree program requires admission to Professional School prior to enrollment.
Description: Topics relevant to understanding the close relationship between energy use, its impact on the environment, and overall economic implications. Green energy technologies (wind, solar, hydro) will be considered along with conventional techniques. Both conventional and non-conventional energy technologies will be discussed.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr
ECEN 3233 Digital Logic Design


Credit hours: 3
Contact hours: Lecture: 2 Lab: 2 Contact: 4
Levels: Undergraduate
Schedule types: Lab, Lecture, Combined lecture and lab
Department/School: Elec & Computer Engr

ECEN 3314 Electronic Devices and Applications

Prerequisites: ECEN 3714, degree program requires admission to Professional School prior to enrollment.

Description: Semiconductor electronic components including MOSFETs, BJTs, JFETs, and OpAmps. Emphasis on device models and use of solid state electronic devices to analyze, synthesize and design amplifiers and switching circuits. SPICE simulations are extensively utilized. Basic building blocks for analog and digital applications. Theoretical concepts and methods are demonstrated and reinforced through laboratory exercises. Course previously offered as ECEN 3313.

Credit hours: 4
Contact hours: Lecture: 3 Lab: 2 Contact: 5
Levels: Undergraduate
Schedule types: Lab, Lecture, Combined lecture and lab
Department/School: Elec & Computer Engr

ECEN 3513 Signal Analysis

Prerequisites: ECEN 3714.


Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 3613 Applied Fields and Waves I

Prerequisites: ECEN 3714 and MATH 2163 and MATH 2233. 

Description: Circuit model of transmission lines, wave propagation, energy transfer, impedance mismatch, and transients. Field analysis of voltage, current, resistance, capacitance, and inductance. Coupled circuits.

Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 3623 Applied Fields and Waves II

Prerequisites: ECEN 3613 and degree program requires admission to Professional School prior to enrollment.


Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 3714 Network Analysis

Prerequisites: ECEN 2714 with a minimum grade of “C” or better and MATH 2233.

Description: Laplace transform, transfer functions, magnetically coupled circuits and two-port networks. Theoretical concepts and methods are demonstrated and reinforced through laboratory exercises. Course previously offered as ECEN 3713.

Credit hours: 4
Contact hours: Lecture: 3 Lab: 2 Contact: 5
Levels: Undergraduate
Schedule types: Lab, Lecture, Combined lecture and lab
Department/School: Elec & Computer Engr

ECEN 3723 Systems I

Prerequisites: ENSC 2113 and ECEN 2714 with a minimum grade of “C” or better, and MATH 2233.

Description: Physical and mathematical modeling of electrical and mechanical dynamic systems. Transient response of first and second order systems. Laplace transform techniques for solving differential equations, transfer functions, frequency response and resonance. Course previously offered as ECEN 3413.

Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 3903 Introduction to Semiconductor Devices

Prerequisites: PHYS 2114 or equivalent.

Description: Crystal structure, the quantum theory of solids. The physics of semiconductor materials and the projection, with an emphasis on applications to semiconductor devices. Same course as PHYS 3313.

Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 3913 Solid State Electronic Devices

Prerequisites: ECEN 2714 with a minimum grade of “C” or better and either PHYS 3313 or ECEN 3903. Degree program requires admission to Professional School prior to enrollment.


Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4010 Technical Problems and Engineering Design

Prerequisites: Consent of instructor.

Description: Individual independent study projects selected in consultation with the instructor; analysis or design problems, literature searches and computer simulations may be involved. Offered for variable credit, 1-12 credit hours, maximum of 12 credit hours.

Credit hours: 1-12
Contact hours: Contact: 1-12 Other: 1-12
Levels: Graduate, Undergraduate
Schedule types: Independent Study
Department/School: Elec & Computer Engr
ECEN 4013 Design of Engineering Systems
Prerequisites: ECEN 3513, ECEN 3714, ECEN 3314, ECEN 3233 and ENSC 3213. ENGL 3323 as co-requisites. Degree program requires admission to professional school prior to enrollment.
Description: Complete design cycle for several small design projects, each including establishing objectives, synthesis, analysis, construction, testing and evaluation. Use of modern lab equipment and fabrication techniques. Development of communication skills.
Credit hours: 3
Contact hours: Lecture: 1 Lab: 4 Contact: 5
Levels: Undergraduate
Schedule types: Lab, Lecture, Combined lecture and lab
Department/School: Elec & Computer Engr

ECEN 4024 Capstone Design
Prerequisites: ECEN 4013; degree program requires admission to Professional School prior to enrollment.
Description: Continuation of ECEN 4013. Student project teams design, build, test and present results for realistic projects from university and industrial sponsors. Formulation of specifications, consideration of alternative solutions, feasibility considerations, detailed system descriptions, economic factors, safety, reliability, aesthetics, ethics and social impact. Course previously offered as ECEN 4023.
Credit hours: 4
Contact hours: Lecture: 3 Lab: 2 Contact: 5
Levels: Undergraduate
Schedule types: Lab, Lecture, Combined lecture and lab
Department/School: Elec & Computer Engr

ECEN 4030 Undergraduate Professional Practice
Prerequisites: Approval of ECEN department head.
Description: Experience in application of electrical engineering principles to typical problems encountered in industry. Solutions to the problems by student participation in the role of engineer or engineering intern. Offered for variable credit, 1-8 credit hours, maximum of 8 credit hours.
Credit hours: 1-8
Contact hours: Contact: 1-8 Other: 1-8
Levels: Undergraduate
Schedule types: Independent Study
Department/School: Elec & Computer Engr

ECEN 4133 Power Electronics
Prerequisites: Degree program requires admission to Professional School prior to enrollment.
Description: Power electronic devices, components, and their characteristics; DC to AC conversion; fundamentals of inverters and waveshaping devices; application aspects; control aspects; characteristics and state-of-the-art of advanced power inverter and power conditioning topologies.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4153 Power System Analysis and Design
Prerequisites: Degree program requires admission to Professional School prior to enrollment.
Description: Power system component models from circuit theory. Formulation and design of the load flow model and the optimum economic generator allocation problem utilizing computer methods.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4213 Embedded Computer Systems Design
Prerequisites: ENSC 3213 and CS 1113.
Description: Degree program requires admission to Professional School prior to enrollment. Design of microprocessor-based systems through proper integration of hardware and software. Serial and parallel communications, sensor interfacing, computer control of external devices, and color graphics hardware. Design of PASCAL and assembly language modules for optimum real-time system performance.
Credit hours: 3
Contact hours: Lecture: 2 Lab: 2 Contact: 4
Levels: Graduate, Undergraduate
Schedule types: Lab, Lecture, Combined lecture and lab
Department/School: Elec & Computer Engr

ECEN 4233 High Speed Computer Arithmetic
Prerequisites: ECEN 3233; degree program requires admission to Professional School prior to enrollment.
Description: Course covers computer arithmetic as applied to general purpose and application-specific processors. Focus is on developing high-speed arithmetic algorithms and understanding their implementation in VLSI technology at the gate level.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4243 Computer Architecture
Prerequisites: ENSC 3213 and ECEN 3233.
Description: Degree program requires admission to Professional School prior to enrollment. Functional organization and hardware design of digital computer systems with emphasis on microprocessor-based systems. CPU organization, features of microprocessors including advanced 32-bit CPU’s, memory system design including cache, virtual memory, error detection and correction, I/O operations, including direct memory access and peripheral interface design.
Credit hours: 3
Contact hours: Lecture: 2 Lab: 2 Contact: 4
Levels: Graduate, Undergraduate
Schedule types: Lab, Lecture, Combined lecture and lab
Department/School: Elec & Computer Engr
ECEN 4273 Software Engineering
Prerequisites: ENSC 3213 or CS 1113, CS 3443.
Description: Functional organization and hardware design of digital computer systems with emphasis on microprocessor-based systems. CPU organization, features of microprocessors including advanced 32-bit CPU's memory system design including cache, virtual memory, error detection and correction, I/O operations, including direct memory access and peripheral interface design. Same course as CS 4273.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4283 Computer Networks
Prerequisites: ENSC 3213 or CS 3443.
Description: Degree program requires admission to Professional School prior to enrollment. Computer networks, distributed systems and their systematic design. Introduction to the use, structure, and architecture of computer networks. Networking experiments to describe network topology. ISO reference model. Same course as CS 4283.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4303 Digital Integrated Circuit Design
Prerequisites: ECEN 3233 and ECEN 3314; degree program requires admission to Professional School prior to enrollment.
Description: Theory of digital and electronics circuits. Digital logic families TTL, IL, ECL, NMOS, CMOS, GaAs. Large signal models for transistors. Implementation at RAM and ROM. Circuit design for LSI and VLSI.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4313 Linear Electronics Circuit Design
Prerequisites: ECEN 3314; degree program requires admission to Professional School prior to enrollment.
Description: Class A and B small-signal, push-pull power, complementary symmetry, differential and operational amplifiers, utilizing field-effect transistors, bipolar transistors, tunnel diodes and integrated circuits. Emphasis on amplification in electronic devices, design and analysis of wide-band amplifier circuitry.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4353 Communication Electronics
Prerequisites: ECEN 3314; degree program requires admission to Professional School prior to enrollment.
Description: Design of tuned voltage and power amplifiers, oscillators and mixers, modulation and detection, and parametric amplifiers.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4413 Automatic Control Systems
Prerequisites: ECEN 3723 or MAE 3723; degree program requires admission to Professional School prior to enrollment.
Description: Properties of feedback control systems, mathematical models of basic components, state-variable models of feedback systems, time-domain analysis, stability, transform analysis, frequency domain techniques, root-locus design of single input single output systems and simple compensation techniques. Same course as MAE 4053.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4503 Random Signals and Noise
Prerequisites: ECEN 3513, ECEN 3714; degree program requires admission to Professional School prior to enrollment.
Description: Analysis of electrical systems using elementary concepts of probability, random variables and random processes. Frequency and time domain response of linear systems driven by random inputs. Statistical properties of electrical noise. Analysis and design of optimum linear systems.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4523 Communication Theory
Prerequisites: ECEN 3513 and ECEN 4503. Degree program requires admission to Professional School prior to enrollment.
Description: Noise in modulation systems. Digital data transmission. Design of optimal receivers. Introduction to information theory.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 4533 Data Communications
Prerequisites: ECEN 4503 as co-requisite.
Description: Degree program requires admission to Professional School prior to enrollment. Signal detection in noise. Tradeoffs between bandwidth signal-to-noise ratio and rate of information transfer. Transmission multiplexing and error handling. Elements of computer network design. Data link protocols.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate, Undergraduate
Schedule types: Lecture
Department/School: Elec & Computer Engr
ECEN 4613 Microwave Engineering  
**Prerequisites:** ECEN 3613; degree program requires admission to Professional School prior to enrollment.  
**Description:** Review of EM and transmission line theory. Microwave network theory: Impedance and admittance matrices, scattering matrix and S-parameters, ABCD and transfer matrices. Signal-flow diagrams. Matching circuits and microwave filters. Passive microwave devices: power dividers, hybrids, couplers, resonators, isolators, and circulators. Class projects such as radar, communication, imaging, or sensing systems.  
**Credit hours:** 3  
**Contact hours:** Lecture: 3 Contact: 3  
**Levels:** Graduate, Undergraduate  
**Schedule types:** Lecture  
**Department/School:** Elec & Computer Engr  

ECEN 4703 Active Filter Design  
**Prerequisites:** ECEN 3613; degree program requires admission to Professional School prior to enrollment.  
**Description:** Introduction to passive filters; operational amplifiers as network elements; filter specifications; design of active filters. Laboratory design projects and computer simulations.  
**Credit hours:** 3  
**Contact hours:** Lecture: 3 Contact: 3  
**Levels:** Graduate, Undergraduate  
**Schedule types:** Lecture  
**Department/School:** Elec & Computer Engr  

ECEN 4743 Introduction to Biomedical Engineering Modeling and Systems  
**Prerequisites:** ECEN 3714, ECEN 4763; degree program requires admission to Professional School prior to enrollment.  
**Description:** An overview of the field of biomedical engineering and an introduction of the modeling approaches implemented in biomedical engineering. Topics include bio-electronics, biomechanics, compartmental modeling, bio-signal processing, biomedical optics, etc. The course will demonstrate a few of major fields of activity in which biomedical engineers are engaged and modeling approaches are implemented.  
**Credit hours:** 3  
**Contact hours:** Lecture: 3 Contact: 3  
**Levels:** Graduate, Undergraduate  
**Schedule types:** Lecture  
**Department/School:** Elec & Computer Engr  

ECEN 4763 Introduction to Digital Signal Processing  
**Prerequisites:** ECEN 3513; degree program requires admission to Professional School prior to enrollment.  
**Credit hours:** 3  
**Contact hours:** Lecture: 3 Contact: 3  
**Levels:** Graduate, Undergraduate  
**Schedule types:** Lecture  
**Department/School:** Elec & Computer Engr  

ECEN 4773 Real Time Digital Signal Processing  
**Prerequisites:** ECEN 4763 or equivalent; degree program requires admission to Professional School prior to enrollment.  
**Description:** DSP Processor architectures and programming. A/D, D/A, polled and interrupt-driven I/O. Realtime implementation of FIR/IIR filters, the FFT, and other DSP algorithms on special purpose DSP hardware from Motorola, Texas Instruments and others. Link between DSP theory and practical implementation.  
**Credit hours:** 3  
**Contact hours:** Lecture: 3 Contact: 3  
**Levels:** Graduate, Undergraduate  
**Schedule types:** Lecture  
**Department/School:** Elec & Computer Engr  

ECEN 4823 Design of Optical Systems  
**Prerequisites:** PHYS 2114; degree program requires admission to Professional School prior to enrollment.  
**Description:** Introduction to optics through the design, construction, and characterization of optical systems. Emphasis on geometrical optics and spectroscopy. Course previously offered as ECEN 3813.  
**Credit hours:** 3  
**Contact hours:** Lecture: 2 Lab: 2 Contact: 4  
**Levels:** Graduate, Undergraduate  
**Schedule types:** Lab, Lecture, Combined lecture and lab  
**Department/School:** Elec & Computer Engr  

ECEN 4843 Design of Lasers and Systems  
**Prerequisites:** ECEN 3613; degree program requires admission to Professional School prior to enrollment.  
**Description:** Introduction of the design of lasers and optical systems based on lasers including the design, construction, and characterization of lasers. Gaussian beams and optics, laser gain materials, laser cavities, advanced topics. Course previously offered as ECEN 4813.  
**Credit hours:** 3  
**Contact hours:** Lecture: 2 Lab: 2 Contact: 4  
**Levels:** Graduate, Undergraduate  
**Schedule types:** Lab, Lecture, Combined lecture and lab  
**Department/School:** Elec & Computer Engr  

ECEN 5000 Thesis or Report  
**Description:** A student studying for the master’s degree will enroll in this course for a maximum of six credit hours. Offered for variable credit, 1-6 credit hours, maximum of 6 credit hours.  
**Credit hours:** 1-6  
**Contact hours:** Contact: 1-6 Other: 1-6  
**Levels:** Graduate  
**Schedule types:** Independent Study  
**Department/School:** Elec & Computer Engr  

ECEN 5030 Professional Practice  
**Description:** Experience in application of electrical engineering principles to typical problems encountered in industry and government engineering design and development projects. Solutions to the problems require participation by the student in the role of junior engineer or engineer-intern. Problem solutions involve economics and ecological considerations as well as technology and must be adequately documented. Offered for variable credit, 1-8 credit hours, maximum of 8 credit hours.  
**Credit hours:** 1-8  
**Contact hours:** Contact: 1-8 Other: 1-8  
**Levels:** Graduate  
**Schedule types:** Independent Study  
**Department/School:** Elec & Computer Engr
ECEN 5060 Special Topics
Prerequisites: Consent of instructor.
Description: Engineering topics not normally included in existing courses. Repeat credit may be earned with different course subtitles assigned. Offered for variable credit, 1-6 credit hours, maximum of 30 credit hours.
Credit hours: 1-6
Contact hours: Contact: 1-6 Other: 1-6
Levels: Graduate
Schedule types: Independent Study
Department/School: Elec & Computer Engr

ECEN 5070 Directed Studies
Prerequisites: Consent of instructor.
Description: Investigation outside of the classroom of topics not normally covered in lecture courses. Offered for variable credit, 1-6 credit hours, maximum of 6 credit hours.
Credit hours: 1-6
Contact hours: Contact: 1-6 Other: 1-6
Levels: Graduate
Schedule types: Independent Study
Department/School: Elec & Computer Engr

ECEN 5113 Power Systems Analysis by Computer Methods
Description: Quasi-static control of power systems and analysis of power systems under abnormal operating conditions. Transient stability studies. Models formulated and solutions outlined for implementation on the computer.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5123 Engineering Systems Reliability Evaluation
Description: Techniques and concepts needed for evaluating the long-term and short-term reliability of a system. Topics include static and spinning generation capacity, transmission, composite, interconnected, and dc system reliability evaluations; and power system security. Applications to systems other than power systems included. For students with little or no background in probability or statistics.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5133 Power Electronics and Renewables
Description: Modeling and control aspects of power electronics for integrating renewable energy systems. Topics covered here will focus on power converter dynamics, indirect converter topologies, PWM technique, sliding mode control of converters, game theory based control, Maximum power point tracking, control of generators for different renewable energy systems. Simulation tools will be discussed as appropriate.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5135 Direct Energy Conversion
Description: Energy conversion techniques and applications; thermo-electrics, thermionics, fuel cells, MHD and other processes involving electrical, mechanical and thermal energies. State-of-the-art developments in direct energy conversion using selected papers from journals and other publications. Gives the student a proper perspective of the possibilities and problems associated with satisfying future energy requirements.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5163 Cyber Physical Systems and Smart Grid
Prerequisites: ECEN 5193.
Description: Introduction to smart grid technologies and applications; advance metering infrastructures, demand response, renewable generation, electric vehicles, and cyberattacks.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5193 Power Economics and Regulation
Prerequisites: Vector calculus, familiarity with complex numbers.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5223 Digital Systems Testing
Prerequisites: ECEN 3233.
Description: Testing of combinational and sequential circuits. Test generation techniques. Design of reliable and testable circuits and systems. Testing for LSI and VLSI.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5233 Embedded Sensor Networks
Prerequisites: Graduate standing or consent of instructor.
Description: Analysis and design of wireless networks, including the integration of sensing, computation, and wireless communication within an embedded system. Mobile sensor networks and body sensor networks. Real world application and new innovations.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr
ECEN 5253 Digital Computer Design
Prerequisites: ECEN 4243 or graduate standing.
Description: Arithmetic algorithms and the design of the arithmetic/logic unit (ALU). Serial and parallel data processing; control and timing systems; microprogramming; memory organization alternatives; input/output interfaces. Same course as CS 5253.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5263 VLSI Digital Systems Design
Prerequisites: ECEN 4303; ECEN 5253 recommended or graduate standing.
Description: Design of very large-scale digital systems on a single chip. Review of MOS technology. Design rules imposed by fabrication techniques. Systematic structures for control and data flow; system timing; highly concurrent systems. Experimental opportunities available.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5283 Computer Vision
Description: The development of machine vision and advanced image understanding techniques for robotics, automated inspection, biomedicine. Object recognition, motion analysis, object tracking, segmentation, representation, and 3-D analysis.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5313 Solid-State Electron I
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5333 Semiconductor Devices
Prerequisites: ECEN 3314 and PHYS 3313 or equivalent.
Description: Semiconductor crystal structure and device fabrication, carrier distribution and transport, pn junction and diode, metal-semiconductor heterojunction, MOSFET, BJT and optoelectronic devices.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5353 Adv Power Electronics
Prerequisites: ECEN 4133.
Description: Characteristics of high power semiconductor devices and the application of such devices to power conditioning, inversion and wave shaping at high power levels.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5363 CMOS Analog Integrated Circuit Design
Prerequisites: ECEN 4313.
Description: Advanced study of solid state CMOS linear integrated circuits. Topics include: Op Amps, comparators, multipliers, D/A and A/D converters and Op Amp building blocks. Op Amp building blocks include, differential pairs, current mirrors, gain, output stages, and references. VLSI layout and circuit simulation using SPICE.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5373 RF Microwave Circuit Design
Prerequisites: ECEN 3314 , ECEN 4613 and ECEN 5333 or equivalent.
Description: Smith chart, single- and multi-port network, filter design, RF/microwave components and modeling, matching and biasing network, amplifier, oscillators and mixers.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5413 Optimal Control
Prerequisites: ECEN 5713 or MAE 5713.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5423 Control of Hybrid Systems
Prerequisites: ECEN 5713 Linear Systems or consent of instructor.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr
ECEN 5433 Robotics Kinematics, Dynamics and Control  
Prerequisites: ECEN 4413 or MAE 4053 or consent of instructor.  
Credit hours: 3  
Contact hours: Lecture: 3 Contact: 3  
Levels: Graduate  
Schedule types: Lecture  
Department/School: Elec & Computer Engr

ECEN 5443 Nonlinear System Analysis and Control  
Prerequisites: ECEN 4413 or MAE 4053.  
Description: Failure of superposition of effects; phase-plane analysis; limit-cycles; Lyapunov stability; hyperstability and input-output stability; controllability and observability of nonlinear systems; feedback linearization; robust nonlinear control system design. Same course as MAE 5463. Course previously offered as ECEN 5723.  
Credit hours: 3  
Contact hours: Lecture: 3 Contact: 3  
Levels: Graduate  
Schedule types: Lecture  
Department/School: Elec & Computer Engr

ECEN 5473 Digital Control Systems  
Prerequisites: ECEN 4413 or MAE 4053.  
Credit hours: 3  
Contact hours: Lecture: 3 Contact: 3  
Levels: Graduate  
Schedule types: Lecture  
Department/School: Elec & Computer Engr

ECEN 5483 Advanced Mechatronics Design  
Prerequisites: MAE 4733 or similar course and consent of instructor.  
Description: Optimizing C programming code for microcontrollers using the assembly language instruction set. RS-232 microcontroller communication protocol. Controller Area Network (CAN) communication protocol plus hands-on CAN bus development boards, advanced topics which could include but are not limited to sensor design, real time operating systems, and advanced communication protocols. Same course as MAE 5483.  
Credit hours: 3  
Contact hours: Lecture: 3 Contact: 3  
Levels: Graduate  
Schedule types: Lecture  
Department/School: Elec & Computer Engr

ECEN 5493 Software Design for Real-Time Distributed Systems  
Prerequisites: ECEN 5483 or MAE 5483 or consent of the instructor.  
Description: Fundamental concepts associated with the design of software for implementation on distributed computer systems using real-time operating systems. Parallel computing in a real-time environment and control algorithm design. State-of-the-art boards including analog-to-digital and digital-to-analog equipment and newest computer-aided software engineering tools.  
Credit hours: 3  
Contact hours: Lecture: 3 Contact: 3  
Levels: Graduate  
Schedule types: Lecture  
Department/School: Elec & Computer Engr

ECEN 5513 Stochastic Systems  
Prerequisites: ECEN 3513 and ECEN 4503 or STAT 4033.  
Description: Theory and applications involving probability, random variables, functions of random variables, and stochastic processes, including Gaussian and Markov processes. Correlation, power spectral density, and non-stationary random processes. Response of linear systems to stochastic processes. State-space formulation and covariance analysis. Same course as MAE 5513.  
Credit hours: 3  
Contact hours: Lecture: 3 Contact: 3  
Levels: Graduate  
Schedule types: Lecture  
Department/School: Elec & Computer Engr

ECEN 5523 Estimation Theory  
Prerequisites: ECEN 5513 or MAE 5513.  
Description: Stochastic model development, parameter estimation and state estimation. The linear model, model order determination, least squares estimation, maximum likelihood estimation, Bayesian estimation, Gaussian random vectors, estimation in linear and Gaussian models, state estimation, the Kalman filter, prediction and smoothing. Same course as MAE 5523.  
Credit hours: 3  
Contact hours: Lecture: 3 Contact: 3  
Levels: Graduate  
Schedule types: Lecture  
Department/School: Elec & Computer Engr

ECEN 5533 Modern Communication Theory  
Prerequisites: ECEN 5513.  
Description: Noise as a random process, analog and digital signal detection in the presence of noise, optimum receiver design using signal space concepts and introduction to information theory. Trade-offs between bandwidth, signal-to-noise ratio and the rate of information transfer. Example system designs include earth satellite, deep space and terrestrial communication systems and computer communication networks.  
Credit hours: 3  
Contact hours: Lecture: 3 Contact: 3  
Levels: Graduate  
Schedule types: Lecture  
Department/School: Elec & Computer Engr
ECEN 5543 Data Transportation and Protection
Description: Data and its representation; finite field matrices, pseudorandom sequences; information protection; space division networks; synchronization; and channel and error control.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5553 Telecommunications Systems
Prerequisites: Graduate standing or consent of instructor.
Description: Surveys the ways and means that voice, data and video are moved long distances. Covers computer networks (Ethernet LAN’s, Internet WAN’s); telephone systems (PSTN, VoIP and cellular telephony); video (MPEG, H.323, and IPTV); and last mile delivery systems.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5563 Principles of Wireless Networks
Prerequisites: ECEN 4283 or CS 4283.
Description: Wireless network operation, planning, mobility management, cellular and mobile data networks based on CDMA, TDMA, GSM; IEEE 802-11 WLANS, Adhoc networks, Bluetooth, power management, wireless geolocation and indoor positioning technique. Same course as CS 5813.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5573 Wireless Communication
Description: Wireless channel characterization: large-scale and small scale fading. Techniques to combat fading; diversity techniques, coding techniques, CDMA, OFDM, MIMO. Cellular concept.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5613 Electromagnetic Theory
Prerequisites: ECEN 3613.
Description: First graduate level treatment of classical electromagnetic theory. Wave equation, potential theory, boundary conditions. Rectangular, cylindrical and spherical wave functions. Conducting and dielectric guiding structures. Scattering and radiation. Introduction to numerical techniques.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5623 Antenna Theory
Prerequisites: ECEN 3613.
Description: Fundamental antenna parameters, including directivity, efficiency, radiation resistance, and pattern. Analysis of dipole, loop, aperture, broad- band, and traveling wave antennas. Array theory. Introduction to numerical techniques used in modern antenna design.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5633 Radar Theory
Prerequisites: ECEN 3613; ECEN 4503 or ECEN 5513.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5643 Antennas and Propagation for Wireless Communications
Prerequisites: ECEN 3613, ECEN 4503.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5653 Microwave Engineering
Prerequisites: ECEN 3613; degree program requires admission to Professional School prior to enrollment.
Description: Review of EM and transmission line theory. Microwave network theory. Impedance and admittance matrices, scattering matrix and S-parameters, ABCD and transfer matrices. Signal-flow diagrams. Matching circuits and microwave filters. Passive microwave devices: power dividers, hybrids, couplers, resonators, isolators, and circulators. Class projects such as radar, communication, imaging, or sensing systems. May not be used for degree credit with ECEN 4613.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr
ECEN 5683 Biomedical Optics
Description: Biomedical optics, also often termed as biophotonics, is a highly interdisciplinary subject on applying light for diagnostic detection and manipulation of biological tissue. This course introduces fundamental concepts and principal technologies of biomedical optics or biophotonics to graduate students and upper-level undergraduate students. The course includes three parts: The first part discusses light-tissue interaction. The second part introduces approaches to modeling photon propagation in tissue. The third part details several representative light-based sensing and imaging technologies for probing biological tissues at different spatial, spectral, and temporal scales for either morphological or functional diagnosis. Topics of therapeutic use of light will also be discussed.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5703 Optimization Applications
Prerequisites: Graduate standing.
Description: A survey of various methods of unconstrained and constrained linear and non-linear optimization. Applications of these methodologies using hand-worked examples and available software packages. This applications oriented course is intended for engineering and science students. Same course as CHE 5703, IEM 5023 & MAE 5703.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5713 Linear Systems
Prerequisites: Graduate standing or consent of instructor.
Description: Introduction to the fundamental theory of finite-dimensional linear systems with emphasis on the state-space representation. Mathematical representations of systems; linear dynamic solutions; controllability, observability, and stability; linearization and realization theory; and state feedback and state observer. Same course as MAE 5713.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5733 Neural Networks
Prerequisites: Graduate standing.
Description: Introduction to mathematical analysis of networks and learning rules, and on the application of neural networks to certain engineering problems in image and signal processing and control systems. Same course as CHE 5733 & MAE 5733.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5753 Digital Processing of Speech Signals
Prerequisites: ECEN 4763 or 5763.
Description: Digital signal processing; speech production; digital modeling of speech; short time analysis and synthesis; the short time Fourier transform, linear predictive coding and solution of the normal equations; vocal tract spectrum calculation; speech coding; homomorphic processing; applications of speech processing. Introduction to more advanced topics as time permits.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5763 Digital Signal Processing
Description: Introduction to discrete linear systems; frequency-domain design of digital filters; quantization effects in digital filters; digital filter hardware, discrete Fourier transforms; high-speed convolution and correlation with application to digital filtering; introduction to Walsh-Fourier theory.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5773 Intelligent Systems
Prerequisites: ECEN 5733.
Description: Introduction to the state-of-the-art intelligent control and system successfully deployed to industrial and defense applications. Emerging intelligent algorithms (e.g., NN, FS, GA, EP, DES); intelligent control architecture (e.g., bottom-up, top-down, semiotics); reinforcement learning and hybrid systems; and case studies and design projects. Same course as MAE 5773.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5783 Medical Imaging
Prerequisites: ECEN 3513, ECEN 4743 or consent of instructor.
Description: A comprehensive introduction to the standard medical imaging modalities used today. Topics include radiation, radiation-interaction with matter, X-ray radiography, ultrasound, computer topography, image reconstruction and analysis, MRI, nuclear medicine, and radiation therapy. The fundamental mathematics underlying each imaging modality is reviewed and the hardware needed to implement each system is examined.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr
ECEN 5793 Digital Image Processing
Prerequisites: ECEN 4763 or ECEN 5763.
Description: Digital image processing including image acquisition and characterization, transforms, coding and compression, enhancement, restoration and segmentation. Use of modern image processing software on Sun and IBM work stations.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5803 Geometrical Optics
Prerequisites: PHYS 3213 or consent of instructor.
Description: Foundations of geometrical optics, geometrical theory of optical imaging, geometrical theory aberrations, image forming instruments. Same course as PHYS 5123.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5823 Physical Optics
Prerequisites: PHYS 3213 or consent of instructor.
Description: Multiple beam interference, diffractions, imaging, near field optical probes of matter, surface plasmons, light scattering from random media, optical coherence tomography- biomedical applications, negative materials, perfect lenses and super resolution. Same course as PHYS 5303.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
_levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5833 Fiber-Optic Communication Systems
Prerequisites: Graduate standing or consent of instructor.
Description: Five generations of fiber-optic communication systems described in detail. Technical advances and increased capability of each system. Historical framework of how technical capability at the time forced technical decisions. A systems engineering point of view, emphasizing optimization of all components of the optical fiber link.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5843 Microelectronic Fabrication
Prerequisites: ECEN 3314.
Description: Contamination control and clean-room, vacuum systems, wafer manufacturing, Photolithography and alternative lithographic techniques. Physical and chemical vapor deposition, oxidation, etching, doping, packaging, formation of semiconductor devices and circuits. A series of Fabrication lab projects is conducted starting from bare silicon wafers to fabricate Optoelectronic circuits. Additional flat fee of $120.00 applies.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5853 Ultrafast Optoelectronics
Prerequisites: Graduate standing or consent of instructor.
Description: Combining ultra fast laser pulses with electronic circuitry. Increased device performance. Optoelectronic/electrical pulses as short as 0.2 psec. High performance areas illustrating the power of advanced techniques in applications.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 5923 Introduction to MEMS
Prerequisites: ECEN 5843 or consent of instructor.
Description: Fundamentals of Microsystems. Topics include: energy transduction mechanisms, energy dissipation modeling, energy methods, mechanics of small scale, fabrication process design, micromachining, electronic interface.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6000 Research
Prerequisites: Consent of major professor.
Description: Independent research for students continuing graduate study beyond the level of the MS degree. Offered for variable credit, 1-16 credit hours, maximum of 36 credit hours.
Credit hours: 1-16
Contact hours: Contact: 1-16 Other: 1-16
Levels: Graduate
Schedule types: Independent Study
Department/School: Elec & Computer Engr

ECEN 6001 PhD Seminar Series
Prerequisites: Approval of ECEN department head.
Description: Seminar series for PhD studies and research.
Credit hours: 1
Contact hours: Lecture: 1 Contact: 1
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6050 Preliminary PhD Research and Proposal
Prerequisites: Consent of adviser.
Description: Independent research and report of an advanced electrical engineering problem. Work performed serves as foundation of the oral PhD preliminary exam.
Credit hours: 3
Contact hours: Contact: 3 Other: 3
Levels: Graduate
Schedule types: Independent Study
Department/School: Elec & Computer Engr
ECEN 6060 Advanced Special Topics
Prerequisites: Consent of instructor.
Description: Advanced engineering topics not normally included in existing courses. Repeat credit may be earned with different course subtitles assigned. Offered for variable credit, 1-6 credit hours, maximum of 30 credit hours.
Credit hours: 1-6
Contact hours: Contact: 1-6 Other: 1-6
Levels: Graduate
Schedule types: Independent Study
Department/School: Elec & Computer Engr

ECEN 6070 Advanced Directed Studies
Prerequisites: Admission into PhD program and consent of instructor.
Description: Investigation outside of the classroom of topics not normally covered in lecture courses. Offered for variable credit, 1-6 credit hours, maximum of 12 credit hours.
Credit hours: 1-6
Contact hours: Contact: 1-6 Other: 1-6
Levels: Graduate
Schedule types: Independent Study
Department/School: Elec & Computer Engr

ECEN 6123 Special Topics in Power Systems
Prerequisites: ECEN 5113.
Description: Selected relevant current topics related to power system operation and planning.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6253 Advanced Topics in Computer Architecture
Prerequisites: ECEN 5253 or CS 5253.
Description: Innovations in the architecture and organization of computers, with an emphasis on parallelism. Topics may include pipelining, multiprocessors, data flow, and reduction machines. Same course as CS 6253.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6263 Advanced VLSI Design and Applications
Prerequisites: ECEN 5223 and ECEN 5263.
Description: System timing. Designing testable integrated circuits. Specialized parallel processing architectures. Application examples.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6363 Analog VLSI for Signal Processing
Prerequisites: ECEN 4273.
Description: Continuation of ECEN 5363. Advanced theory and practice of analog VLSI design methodology. Very large scale design and implementation of signal processing solutions, including over sampled A/Ds, neural networks and filters.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6423 System Identification
Prerequisites: ECEN 5473 or ECEN 5713 or MAE 5473 or MAE 5713.
Description: Linear and nonlinear system modeling of random systems. Models of linear time-invariant systems, nonparametric methods and preliminary model development, parameter estimation methods, convergence and consistency, asymptotic distributions of parameter estimates. Nonlinear modeling. Same course as MAE 6423.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6453 Adaptive Control
Prerequisites: ECEN 5473 or ECEN 5713 or MAE 5473 or MAE 5713.
Description: Analysis and design of control techniques that modify their performance to adapt to changes in system operation. Review of systems analysis techniques, including state variable representations, linearization, discretization, covariance analysis, stability, and linear quadratic Gaussian design. On-line parameter estimation, model reference adaptive systems, self-tuning regulators, stable adaptive systems. Same course as MAE 6453. Course previously offered as ECEN 6450.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6463 Advances in NonLinear Control
Prerequisites: ECEN 5463 or MAE 5463.
Description: Introduction to vector fields and Lie algebra; controllability and observability of non-linear systems; local decompositions; input-output and state space representation of non-linear systems; feedback linearization; controlled invariance and distribution; control of Hamiltonian systems. Same course as MAE 6463.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr
ECEN 6483 Robust Multivariate Control Systems
Prerequisites: ECEN 5713 or MAE 5713.
Description: Introduction to multivariable systems: SISO robustness vs. MIMO robustness; multivariable system poles and zeros; MIMO transfer functions; multivariable frequency response analysis; multivariable Nyquist theorem; performance specifications; stability of feedback systems; linear fractional transformations (LFT’s); parameterization of all stabilizing controllers; structured singular value; algebraic ricatti equations; H2 optimal control; H-infinity controller design. Same course as MAE 6483.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6523 Information Theory
Prerequisites: ECEN 5513 or consent of instructor.
Description: Mathematical theory of information (Shannon theory) including information measure and transmission rates and capacities. Source coding theory including algebraic and error-correcting codes. Design of waiver-forms for noise immunity. Information transfer in learning systems.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6803 Photonics I: Advanced Optics
Prerequisites: ECEN 3813 or PHYS 3213 or consent of instructor.
Description: Advanced optics including spectral and time characteristics of detectors, characteristics of lasers, time, spectral and spatial parameters of laser emission, interferometric techniques, and nonlinear effects such as two-photon absorption and second and third harmonic generations. Emphasis on ultrashort laser pulses. Same course as CHEM 6803 & PHYS 6803.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6810 Photonics II: THz Photonics and THz-TD
Prerequisites: ECEN 6803.
Description: Concepts and techniques of driving electronic circuitry with ultra short laser pulses to generate and detect freely propagating pulses of THz electromagnetic radiation using several operational research systems. Same course as CHEM 6810 & PHYS 6810. Course previously offered as ECEN 6811. Offered for fixed credit, maximum of 4 credit hours.
Credit hours: 1
Contact hours: Lab: 2 Contact: 2
Levels: Graduate
Schedule types: Lab
Department/School: Elec & Computer Engr

ECEN 6820 Photonics II: Spectroscopy II
Prerequisites: ECEN 6803.
Description: Operating principles and applications of laser spectroscopy of atoms, molecules, solids and complex fluids. Absorption, emission, photon correlation, coherence, time resolved Fourier transform. Raman spectroscopy and non-linear optical. Same course as CHEM 6820 & PHYS 6820. Course previously offered as ECEN 6821. Offered for fixed credit, maximum of 4 credit hours.
Credit hours: 1
Contact hours: Lab: 2 Contact: 2
Levels: Graduate
Schedule types: Lab
Department/School: Elec & Computer Engr

ECEN 6823 Advanced Optical Techniques
Prerequisites: ECEN 5953.
Description: State-of-the-art optical devices and research methodologies. Investigation and discussion of contemporary developments in non-linear optical devices and laser applications. Includes both analytical and experimental techniques.
Credit hours: 3
Contact hours: Lecture: 3 Contact: 3
Levels: Graduate
Schedule types: Lecture
Department/School: Elec & Computer Engr

ECEN 6830 Photonics II: Spectroscopy III
Prerequisites: ECEN 6803.
Description: Investigation and discussion of contemporary developments in non-spectroscopy and non-linear optical. Same course as CHEM 6820 & PHYS 6820. Course previously offered as ECEN 6831. Offered for 1 fixed credit hour, maximum of 4 credit hours.
Credit hours: 1
Contact hours: Lab: 2 Contact: 2
Levels: Graduate
Schedule types: Lab
Department/School: Elec & Computer Engr

ECEN 6840 Photonics III: Microscopy I
Prerequisites: CHEM 3553 or consent of instructor.
Description: State-of-the-art optical devices and research methodologies. Investigation and discussion of contemporary developments in non-spectroscopy and non-linear optical. Same course as CHEM 6830 & PHYS 6830. Course previously offered as ECEN 6831. Offered for 1 fixed credit hour, maximum of 4 credit hours.
Credit hours: 1
Contact hours: Lab: 2 Contact: 2
Levels: Graduate
Schedule types: Lab
Department/School: Elec & Computer Engr
ECEN 6843 Advanced Microelectronic Fabrication  
**Prerequisites:** ECEN 5843.  
**Description:** Photolithography, wet and dry etching, thermal and electron beam evaporation, photomask design using L-Edit, silicon devices processing, quartz devices processing, silicon-on-sapphire devices processing, GaAs devices processing and MEMS devices processing.  
**Credit hours:** 3  
**Contact hours:** Lecture: 3 Contact: 3  
**Levels:** Graduate  
**Schedule types:** Lecture  
**Department/School:** Elec & Computer Engr  

ECEN 6850 Photonics III: Microscopy II  
**Prerequisites:** CHEM 3553 or consent of instructor.  
**Description:** Advanced techniques of scanning probe microscopy (SPM). Magnetic force microscopy, Kelvin force microscopy, scanning probe microscopy (STM) in vacuum. Characterization of materials with SPM. Nanolithography with SPM. Device manufacturing and analysis. Same course as CHEM 6850 & PHYS 6850. Course previously offered as ECEN 6851. Offered for 1 fixed credit hour, maximum of 4 credit hours.  
**Credit hours:** 1  
**Contact hours:** Lab: 2 Contact: 2  
**Levels:** Graduate  
**Schedule types:** Lab  
**Department/School:** Elec & Computer Engr  

ECEN 6860 Photonics III: Microscopy III and Image Processing  
**Prerequisites:** ECEN 5793.  
**Description:** Digital image processing, including projects. Image acquisition and display, image enhancement, geometric operations, linear and nonlinear filtering, image restoration, edge detection, image analysis, morphology, segmentation, recognition, and coding/compression. Same course as CHEM 6860 & PHYS 6860. Offered for fixed credit hours, maximum of 4 credit hours.  
**Credit hours:** 1  
**Contact hours:** Lab: 2 Contact: 2  
**Levels:** Graduate  
**Schedule types:** Lab  
**Department/School:** Elec & Computer Engr  

ECEN 6870 Photonics IV: Synthesis and Devices I  
**Prerequisites:** ECEN 6803 and ECEN 6840.  
**Description:** Preparation of functional nanostructures and related optical/electronic devices. Physical and chemical methods of thin film deposition. Engineering of prototypes of light emitting diodes, sensors, optical limiting coatings, lithographic patterns. Same course as CHEM 6870 & PHYS 6870. Course previously offered as ECEN 6871. Offered for 1 fixed credit hour, maximum of 4 credit hours.  
**Credit hours:** 1  
**Contact hours:** Lab: 2 Contact: 2  
**Levels:** Graduate  
**Schedule types:** Lab  
**Department/School:** Elec & Computer Engr  

ECEN 6880 Photonics IV: Semiconductor Devices, Testing and Characterization  
**Prerequisites:** ECEN 6803 and ECEN 6840.  
**Description:** Test and characterization of semiconductor and optoelectronic devices. Hall effect, four point probe, CV and IV measurements, optical pump-probe, photoluminescence and electro-optics sampling. Same course as CHEM 6880 & PHYS 6880. Course previously offered as ECEN 6881. Offered for 1 fixed credit hour, maximum of 4 credit hours.  
**Credit hours:** 1  
**Contact hours:** Lab: 2 Contact: 2  
**Levels:** Graduate  
**Schedule types:** Lab  
**Department/School:** Elec & Computer Engr  

**Undergraduate Programs**  
- Computer Engineering, BSCP (http://catalog.okstate.edu/engineering-architecture-technology/electrical-computer-engineering/computer-bscp)  
- Electrical Engineering, BSEE (http://catalog.okstate.edu/engineering-architecture-technology/electrical-computer-engineering/electrical-bsee)  

**Graduate Programs**  
The School of Electrical and Computer Engineering offers three graduate degrees, all in electrical engineering: Master of Engineering (MENGEE), Master of Science (MSEE) and Doctor of Philosophy (PhDEE).

These graduate degree programs are flexible in course selection and emphasis. Both the Mater of Engineering and the Master of Science programs are available online.

The Master of Engineering degree program is tailored to students who wish to gain advanced knowledge and expertise in subject areas associated with their professional pursuits. This non-research, non-thesis, instructional program is ideal for Distance Education students or for baccalaureate graduates interested in professional development to enhance their competitiveness in the workplace. It is well-suited for students who have little interest in a research-centric education.

The Master of Science degree emphasizes advanced mathematics, theory, design and research. It is intended for students interested in cutting-edge careers or who want to prepare for advanced research associated with the PhD program. This degree combines coursework with research that allows students to expand their knowledge in an in-
depth area of electrical engineering or computer engineering. The MSEE program culminates with the defense of a thesis.

The Doctor of Philosophy degree is designed to prepare students for positions in academia, industry and government. This degree emphasizes the creation of new knowledge through the in-depth research process, as documented in the doctoral dissertation.

The School of Electrical and Computer Engineering also offers a "4+1" degree program that combines the BSEE/BScPE degree programs with the MEngEE degree program. The "4+1" program is only available to OSU baccalaureate students. It is designed to be completed in five years and to give students a broad-based education in electrical engineering or computer engineering along with a highly in-depth education in a few key areas. This program is ideal for those students who want advanced knowledge to enhance their competitiveness in the workforce and to satisfy their longing for in-depth knowledge that cannot be obtained in the baccalaureate degrees. Specific requirements for the "4+1" program are available on the web in the document entitled "Memorandum to Graduate Students;" see https://ece.okstate.edu/.

Students typically select coursework and participate in research and design projects in the following areas:

- Communication systems, cybersecurity and networks
- Control systems, robotics and mechatronics
- Analog, mixed-signal and RF electronics
- Computer architecture, VLSI digital circuits and arithmetic
- Electromagnetics and THz sciences
- Microcontrollers and embedded control
- Photonics and electro-optics
- Digital signal, image and video processing
- Energy and power
- Bioengineering

Admission Requirements

Admission to the Graduate College, as described under "General Regulations" in the "Graduate College" section of the University Catalog is required. Graduation from an electrical engineering or computer engineering program accredited by the ABET and sufficient GRE scores are required for admission to the School of Electrical and Computer Engineering.

Graduates from non-engineering fields such as mathematics, physics and computer science are also admitted to the School of Electrical and Computer Engineering graduate programs if an evaluation of the applicant's official transcript indicates that the applicant is prepared to succeed in graduate-level course work in electrical and computer engineering, or can be expected to do so after a reasonable amount of remedial coursework has been completed. This condition also applies to graduates of unaccredited engineering programs and engineering technology programs.

Degree Requirements

The Master of Engineering degree in Electrical Engineering (MEngEE) is awarded to those students who successfully complete an approved plan of study. The degree requires 33 credit hours of coursework; a thesis is not required. The plan of study requires, at a minimum, 18 hours of 5000-level courses in electrical and computer engineering. Most plans of study include additional 5000-level courses, depending upon the background and particular educational goals of the student. Additional remedial work in undergraduate electrical and computer engineering courses may be required for students who do not have a sufficient background in electrical engineering. Specific requirements for the MEngEE program are available on the web in the document entitled "Memorandum to Graduate Students;" see https://ece.okstate.edu/.

The Master of Science degree in Electrical Engineering (MSEE) is awarded to those students who successfully complete an approved plan of study. The degree requires 24 credit hours of coursework plus 6 credit hours for the thesis. In addition to the thesis requirement, the plan of study requires, at a minimum, 18 hours of 5000-level courses in electrical and computer engineering. Most plans of study include additional 5000-level courses, depending upon the background and particular educational goals of the student. Each student is encouraged to include courses in supporting disciplines such as mathematics, physics, computer science or other engineering fields. Additional remedial work in undergraduate electrical and computer engineering courses may be required for students who do not have a sufficient background in electrical engineering. Specific requirements for the MSEE program are available on the web in the document entitled "Memorandum to Graduate Students;" see https://ece.okstate.edu/.

The School of Electrical and Computer Engineering also participates in several interdisciplinary degree programs (See "Graduate Programs" under "Industrial Engineering and Management," and "Telecommunications Management" the "Graduate College" section of the Catalog.).

Faculty

Jeffrey L. Young, PhD, PE—Professor and Head
Professor and OSURF Endowed Chair: Jeffrey L. Young, PhD, PE
Regents Professor: Gary Yen, PhD
Associate Dean for CEAT Research, Professor and Henry Bellmon Chair: Charles F. Bunting, PhD
Cal and Marilyn Vogt Professor: Guoliang Fan, PhD
Earl and Carolyn Glimp Professor: James Stine, PhD
Professors: H. Jack Allison, PhD, PE (emeritus); Charles M. Bacon, PhD (emeritus); James E. Baker, PhD (emeritus); Richard L. Cummins, PhD (emeritus); Daniel R. Grischkowsky, PhD (emeritus); Martin T. Hagan, PhD, PE (emeritus); Louis Johnson, PhD (emeritus); Subhash Kak, PhD (emeritus); Jerzy S. Krasinski, PhD; Daqing Piao, PhD; Rama Ramakumar, PhD, PE (emeritus); Ronald P. Rhoten, PhD, PE (emeritus); Keith A. Teague, PhD, PE; James C. West, PhD; Rama Ramakumar, PhD (emeritus); Weili Zhang, PhD
Professor of Practice: Michael Gard, PhD, PE
Associate Professors: Chriswell G. Hutchens, PhD, PE (emeritus); Carl D. Latino, PhD; George Scheets, PhD (emeritus); Weihua Sheng, PhD
Assistant Professors: Sabit Ekin, PhD; Nishantha Ekneligoda, PhD; John Hu, PhD; John O’Hara, PhD; Ickhyun Song, PhD