Electrical & Computer Engineering (ECE)

ECE 111. Introduction to Electrical and Computer Engineering. 3 Credits.
Introduction to electrical and computer engineering problem solving, design and professional issues. 3 lectures. Prereq: MATH 103.

ECE 173. Introduction to Computing. 4 Credits.
Programming in a high level language with applications to engineering computation, analysis, and design. 3 lectures, 1 2-hour laboratory. Prereq: MATH 103 or higher.

ECE 193. Undergraduate Research. 1-5 Credits.

ECE 194. Individual Study. 1-5 Credits.

ECE 196. Field Experience. 1-15 Credits.

ECE 199. Special Topics. 1-5 Credits.

ECE 275. Digital Design. 4 Credits.
Introduction to computer arithmetic, designing combinatorial circuits, and designing basic sequential circuits. 3 lectures, 1 two-hour laboratory. Prereq: MATH 105.

ECE 291. Seminar. 1-3 Credits.

ECE 292. Global Practicum: Study Abroad. 1-15 Credits.
Pre-Arranged study at accredited foreign institutions (study abroad), domestic institutions (National Student Exchange) or on approved study abroad programs. Pre-requisite: Sophomore standing and prior approval by International Student and Study Abroad Services and major department. Graded 'P'or 'F' (Undergraduate), or 'S' or 'U' (Graduate).

ECE 293. Undergraduate Research. 1-5 Credits.

ECE 294. Individual Study. 1-5 Credits.

ECE 299. Special Topics. 1-5 Credits.

ECE 301. Electrical Engineering I. 3 Credits.
Introduction to electrical engineering for non-majors. Fundamental laws of circuit analysis. Steady-state and transient analysis of DC and AC circuits. 3 lectures. Prereq: MATH 259 or MATH 265, PHYS 252.

ECE 303. Electrical Engineering II. 3 Credits.
Electronic circuits and their applications. Electromechanical energy conversion. Transformers, DC and AC machines. 3 lectures. Prereq: ECE 301.

ECE 306. Electrical Engineering Lab I. 1 Credit.
Electronic instruments and measurements. Applications to electrical and electronic circuits, power devices, and systems. 1 two-hour laboratory. Prereq: ECE 301.

ECE 311. Circuit Analysis II. 4 Credits.
Analysis of single-phase and three-phase circuits. Laplace transforms in circuit analysis. Fourier series. Two-port networks. 3 one-hour lectures, 1 two-hour laboratory. Prereq: EE 206 with a grade of C or better. Coreq: MATH 266.

ECE 320. Electronics I. 3 Credits.
Characterization, modeling, and analysis of digital circuits using diodes, BJTs, FETs, and Op Amps. 4 one-hour lectures, 1 two-hour laboratory each week for 10 weeks. Prereq: EE 206.

ECE 321. Electronics II. 2 Credits.
Characterization, modeling, and analysis of digital and analog circuits using diodes, BJTs, FETs, and Op Amps. 1 one-hour lecture, 1 two-hour laboratory each week for 6 weeks. Prereq: EE 206.

ECE 331. Energy Conversion. 4 Credits.
Magnetic circuits, transformers, DC and AC rotating machines. 3 one-hour lectures, 1 two-hour laboratory. Coreq: ECE 311.

ECE 341. Random Processes. 3 Credits.
Principles of probability. Application of probability and statistics to electrical and computer engineering problems. 3 lectures. Prereq: MATH 266.

ECE 343. Signals & Systems. 4 Credits.
Discrete-time and continuous-time signals and systems. Linearity, frequency response, difference and differential equations, transform techniques. Course covers a variety of essential mathematical concepts including complex arithmetic, difference and differential equations, convolution, Laplace transforms, z-transforms, and various Fourier representations. Prereq: ECE 311.

ECE 351. Applied Electromagnetics. 4 Credits.
Lecture and laboratory introduction to electromagnetic waves in linear media, effects of boundaries, transmission lines, electrostatics, and magnetostatics. Introduction to time dependence and engineering applications. 4 lectures, 1 two-hour laboratory. Coreq: ECE 311.

ECE 373. Assembly Programming. 3 Credits.
Machine language, assembly language, and related hardware concepts, assembly language programming, macros and subroutines, system facilities and macros. Prereq: ECE 173, ECE 275 with a grade of C or better. Cross-listed with CSCI 373.

ECE 374. Computer Organization. 4 Credits.
Organization and structure of the major sections of a computer: CPU, memory, and I/O system organization and implementation issues. 3 lectures, 1 two-hour VHDL-based laboratory. Prereq: ECE 173, ECE 275 with a grade of C or better.

ECE 375. Digital Design 2. 3 Credits.
Sequential circuit design, design of optimized arithmetic circuits including adders, subtractors, multipliers and dividers, floating point arithmetic, and behavioral and structural VHDL. 2 lectures, 1 two-hour laboratory. Prereq: ECE 173, ECE 275.

ECE 376. Embedded Systems. 4 Credits.
Use of microcontrollers for data acquisition and device control. Includes assembly language and high-level programming, serial and parallel I/O, timers and interface design. 3 lectures, 1 two-hour laboratory. Prereq: ECE 173, ECE 275, EE 206.

ECE 379. Global Seminar. 1-6 Credits.
NDSU instructed experience or field study in a foreign country. Conducted in English for residence credit. Pre-requisite: Prior approval by International Student and Study Abroad Services and major department. May be repeated. Standard Grading.

ECE 391. Seminar. 1-3 Credits.

ECE 392. Global Practicum: Study Abroad. 1-15 Credits.
Pre-Arranged study at accredited foreign institutions (study abroad), domestic institutions (National Student Exchange) or on approved study abroad programs. Pre-requisite: Sophomore standing and prior approval by International Student and Study Abroad Services and major department. Graded 'P'or 'F' (Undergraduate), or 'S' or 'U' (Graduate).

ECE 393. Undergraduate Research. 1-5 Credits.

ECE 394. Individual Study. 1-3 Credits.

ECE 397. Fe/Coop Ed/Internship. 1-4 Credits.

ECE 399. Special Topics. 1-5 Credits.

ECE 401. Design I. 1 Credit.
Capstone experience in formulation and design of a system or device. Basic project planning and software tools. 1 lecture. Coreq: ECE 320.

ECE 403. Design II. 2 Credits.
Capstone experience in formulation and design of a system or device. 2 two-hour design laboratories. Prereq: ECE 401, Senior standing.

ECE 405. Design III. 3 Credits.
Capstone experience in formulation and design of a system or device. 3 two-hours design laboratories. Prereq: ECE 403.

ECE 411. Optics for Scientists and Engineers. 3 Credits.
Introduction to modern optics. Geometric optics, electromagnetic nature of light, polarization, interference, diffraction, fiber optics. Prereq: PHYS 252. Co-req: ECE 411L. Cross-listed with PHYS 411. {Also offered for graduate credit - see ECE 611.}.

ECE 411L. Optics for Scientists and Engineers Laboratory. 1 Credit.
Required laboratory for ECE/PHYS 411. Ten optics experiments plus a major-related optics project. Prereq: PHYS 252. Co-req: ECE 411. {Also offered for graduate credit - see 611L.}.

ECE 413. Lasers for Scientists and Engineers. 3 Credits.
Lecture and laboratory introduction to lasers. Spontaneous and stimulated transitions, line-broadening, gain, gain saturation, optical resonators, Fabry-Perot interferometers, theory of laser oscillation, rate equations, transverse modes, coherence, and Gaussian beams. Prereq: PHYS 252. Cross-listed with PHYS 413. {Also available for graduate credit - See ECE 613.}.

ECE 415. Elements of Photonics. 3 Credits.
Analysis of optical systems using the matrix formulation, wave propagation in anisotropic media, electro-optic effect and laser modulation, physical origin of optical non-linearities, phase matching, optical second harmonic and parametric generation. Prereq: PHYS 252. Cross-listed with PHYS 415. {Also offered for graduate credit - See ECE 615.}.

ECE 417. Optical Signal Transmission. 3 Credits.
Optical signal transmission including geometric optics and modal analysis for homogeneous and inhomogeneous light guides. Systems studies including coupling, inter-symbol interference, sources, photodetectors, and modulation. Prereq: ECE 351. Cross-listed with PHYS 417. {Also offered for graduate credit - see ECE 617.}.

ECE 421. Communication Circuits. 3 Credits.
Resonant circuits and tuned amplifiers, oscillators, modulators and demodulators, phase-locked loops, and power amplifiers. Analysis, design, and applications in communication systems. 3 lectures. Prereq: ECE 321. {Also offered for graduate credit - see ECE 621.}.

ECE 423. VLSI Design. 3 Credits.
Analysis and design of digital integrated circuits. Characteristics and applications of logic gates and regenerative logic circuits. 3 lectures. Prereq: ECE 320. {Also offered for graduate credit - see ECE 623.}.

ECE 424. Analog VLSI. 3 Credits.
Design, analysis, and simulation of analog VLSI circuits including operational amplifiers, current mode circuits, oscillators, translinear circuits, and phase locked-loops. Design automation for analog circuits. Prereq: ECE 311, ECE 321. {Also offered for graduate credit - see ECE 624.}.

ECE 425. Introduction to Semiconductor Devices. 3 Credits.
Properties and applications of semiconductors and solid-state electronic devices. Semiconductors, junctions, and transistors. 3 lectures. Prereq: ECE 320. {Also offered for graduate credit - see ECE 625.}.

ECE 426. Nanoelectronics. 3 Credits.
This course is designed to provide students with knowledge and understanding of physical background and applications of nanoelectronics, which reflects science and technology after the silicon-based microelectronics. The course will cover electrical and optical properties of materials and nanostructures, fabrication of nanostructures, nanoelectronic devices including resonant-tunneling devices, transistors, and single-electron transfer devices, as well as engineering applications of nanoscience and nanotechnology. Prereq: MATH 266, PHYS 252 and ECE 320.

ECE 427. Packaging for Electronics. 3 Credits.
Processes and materials for packaging of electronic components and devices, including integrated circuit chips, chip packages, and board level packaged systems; boards and substrates technology; quality and reliability of electronic packages. Open to all engineering majors. Prereq: Junior standing. Cross-listed with IME 427. {Also offered for graduate credit - see ECE 627.}.

ECE 429. Introduction to IC Fabrication. 3 Credits.
This course examines issues about fabrication methods and procedures. Topics will include implantation, pattern transfer and process integration. Cross-listed with IME 429. {Also offered for graduate credit - see ECE 629.}.

ECE 431. Power Systems. 3 Credits.
Electrical characteristics of high voltage lines. Symmetrical components, per unit system, and transformers. Matrix methods, load flow, and fault analysis. 3 lectures. Prereq: ECE 311. {Also offered for graduate credit - see ECE 631.}.

ECE 432. Computational Methods in Power Systems. 3 Credits.
Power flow, optimal power flow, state estimation, contingency analysis, unit commitment, security assessment, small signal and dynamic stability, voltage stability, emerging algorithms for blackout and vulnerability assessment in power systems. Co-req: ECE 431. {Also offered for graduate credit - see ECE 632.}.

ECE 433. Power Systems Design. 3 Credits.
Unbalanced power systems, economic dispatch, transients in power systems, power system stability, power system protection. 3 lectures. Prereq: ECE 311. {Also offered for graduate credit - see ECE 633.}.

ECE 437. Power Electronics. 3 Credits.
Characteristics and modeling of power electronic devices. Rectifiers, choppers, and inverters and their applications in power supplies and motor drives. 3 lectures. Prereq: ECE 321. {Also offered for graduate credit - see ECE 637.}.

ECE 438. Electric Drives. 4 Credits.
Characteristics of loads and drive train, power converters, four quadrant ac/dc drives, DSP control, drives for special motors, applications including electric vehicles. 3 lectures, 1 two-hour laboratory. Prereq: ECE 331 with a grade of C or better, ECE 437 with a grade of C or better. {Also offered for graduate credit - see ECE 638.}.

ECE 443. Communications I. 4 Credits.
Communications theory and design with an emphasis on spectral techniques. Modulation and noise effects. 3 lectures, 1 two-hour laboratory. Prereq: ECE 341 and ECE 343. {Also offered for graduate credit - see ECE 643.}.

ECE 444. Applied Digital Signal Processing. 3 Credits.
Digital signal processing theory balanced with practical application. Includes design of FIR, IIR, and adaptive filters; Fast Fourier Transforms; sampling theory; implementation techniques; multi-rate processing. Emphasizes system implementation using development tools and DSP hardware. 3 lectures. Prereq: ECE 173, ECE 343. {Also offered for graduate credit - see ECE 644.}.

ECE 445. Communications II. 3 Credits.
Continuation of ECE 443. Digital communications systems. Optimum receivers. Information theory and coding. 2 lectures. Prereq: ECE 443. {Also offered for graduate credit - see ECE 645.}.

ECE 448. Image Analysis I. 3 Credits.
Image acquisition, resolution, enhancement, restoration, and equalization. Illuminations, reflectance, and noise considerations. Segmentation, shape characterization, and object recognition. Simulation examples, computer problems, and gathering of actual scientific images via camera and computer. Prereq: EC 343 or instructor approval. {Also offered for graduate credit - see ECE 648.}.

ECE 451. RF and Microwave Circuit Analysis and Design for Wireless Systems. 3 Credits.
This course will focus on the analysis and design of Radio Frequency (RF) and microwave circuits. In particular, circuits such as oscillators, filters, power dividers, amplifiers, mixers and modulators will be studied for wireless systems. Prereq: ECE 321 and ECE 351. {Also offered for graduate credit - see ECE 651.}.

ECE 453. Signal Integrity. 3 Credits.
Topics in system level signal integrity are presented. The construction and design of passive printed circuit cards are discussed, with computer aided design software used for analysis and class presentations. Circuit card fabrication issues and case examples of applications are discussed. Prereq: ECE 311, ECE 351. {Also offered for graduate credit - see ECE 653.}.

ECE 455. Designing for Electromagnetic Compatibility. 3 Credits.
Principles and methods concerning electronic system designs that are not sources of or susceptible to electromagnetic interference. 3 lectures. Laboratory. Prereq: ECE 343, ECE 351. {Also offered for graduate credit - see ECE 655.}.

ECE 461. Control Systems I. 4 Credits.
Modeling and control of dynamic systems, including root-locus, Bode plots, and Nichols charts. 3 lectures, 1 two-hour laboratory. Prereq: ECE 343. {Also offered for graduate credit - see ECE 661.}.

ECE 463. Modern Control. 3 Credits.
Analysis and design of controllers for linear and non-linear systems using state-space methods. Design to specifications, controllability, observability, stability, optimization, and state-estimation. 3 lectures. Prereq: ECE 343. {Also offered for graduate credit - see ECE 663.}.

ECE 470. Fault Tolerant Digital Systems. 3 Credits.
Design and analysis of reliable digital systems through robust information coding, fault avoidance, and fault-tolerance. 3 lectures. Prereq: ECE 275. {Also offered for graduate credit - see ECE 670.}.

ECE 471. Computer Systems Design and Implementation. 3 Credits.
Design and implementation of reliable, interrupt driven systems. Use of development tools. System components issues including co-processors, buses, run-time. Prereq: ECE 376, ECE 401, CSCI 474.

ECE 472. Design Automation of VLSI Circuits. 3 Credits.
Electronic design automation algorithms utilized by software tools, which are used for the design automation of VLSI integrated circuits. This course will cover design steps including circuit synthesis, technology mapping, formal verification, floorplanning, placement, and routing. Prereq: ECE 173, 275 with a grade of C or better. {Also offered for graduate credit - see ECE 672.}.

ECE 474. Computer Architecture. 3 Credits.
Topics pertaining to computer architecture will include: pipelining, caches, memory, I/O superscalar and out-of-order instruction execution, speculative execution, vector execution, multithreading, and multiprocessors. Prereq: ECE 374. {Also offered for graduate credit - see ECE 674.}.

ECE 476. Advanced Embedded Systems. 4 Credits.
Specification, design, development, and test of modern embedded systems using a high-level programming language. 3 lectures, 1 two-hour laboratory. Prereq: ECE 376. {Also available for graduate credit, See ECE 676.}.

ECE 477. Hardware Design for Machine Learning. 3 Credits.
Hardware-aware neural network (NN) design in NVidia Developer kit with OpenCV python programming. MAC design for NN and alternate neural network implementations using emerging technologies. Advanced topics in Hardware-aware neural network designs such as Binary nets, FFT-based neural nets, In-compute Memory and near-compute memory. 2 lectures, 1 two-hour laboratory. Prereq: ECE 374 and ECE 375. {Also offered for graduate credit - See ECE 677.}.

ECE 479. Formal Verification. 3 Credits.
Formal verification methods for hardware, software, and embedded systems such as theorem proving, property-based verification, equivalence checking, notions of correctness such as refinement, methods used in computer-aided verification including BDDs and SAT procedures. Prereq: ECE 275 and ECE 173 or CSCI 160. {Also offered for undergraduate credit - see ECE 679.}.

ECE 483. Instrumentation for Engineers. 3 Credits.
Study of instrumentation including design, fabrication, and application. Prereq: Senior standing. {Also offered for graduate credit - see ECE 683.}.

ECE 485. Biomedical Engineering. 3 Credits.
Unified study of engineering techniques and basic principles in physiological systems. Focus on membrane biophysics, biological modeling, compartmental analysis, and systems control theory. Prereq: Senior standing. {Also offered for graduate credit - see ECE 685.}.

ECE 486. Biosensing Technology. 3 Credits.
Biosensors are defined as analytical devices incorporating a biological material, a biologically derived material or a biomimic associated with or integrated within a physicochemical transducer or transducing microsystem, which may be optical, electrochemical, thermometric, piezoelectric, magnetic or micromechanical. This course provides instruction in the basic science and engineering concepts required to understand the design and application of biosensors. This module serves as an introduction to some of the biosensors and measurement techniques. Prereq: Senior standing. {Also available for graduate credit - see ECE 686.}.

ECE 487. Cardiovascular Engineering. 3 Credits.
This course includes the application of engineering techniques to cardiovascular physiology and medicine. Basic cardiac and vascular physiology will be presented, modeling techniques will be examined. Instrumentation, measurement theory, and assist devices will be discussed. Prereq: Senior standing. {Also offered for graduate credit - see ECE 687.}.

ECE 488. Cardiovascular Engineering II. 3 Credits.
Analysis, design, and research methods related to modeling and simulating the cardiovascular system. Prereq: ECE 487. {Also offered for graduate credit - see ECE 688.}.

ECE 491. Seminar. 1-5 Credits.

ECE 492. Global Practicum: Study Abroad. 1-15 Credits.
Pre-Arranged study at accredited foreign institutions (study abroad), domestic institutions (National Student Exchange) or on approved study abroad programs. Pre-requisite: Sophomore standing and prior approval by International Student and Study Abroad Services and major department. Graded 'P'or 'F' (Undergraduate), or 'S' or 'U' (Graduate).

ECE 493. Undergraduate Research. 1-5 Credits.

ECE 494. Individual Study. 1-5 Credits.

ECE 496. Field Experience. 1-15 Credits.

ECE 499. Special Topics. 1-5 Credits.

ECE 611. Optics for Scientists and Engineers. 3 Credits.
Introduction to modern optics. Geometric optics, electromagnetic nature of light, polarization, interference, diffraction, fiber optics. Corequisite laboratory with major related optics project. Coreq: PHYS 611L. Cross-listed with PHYS 611. {Also offered for undergraduate credit - see ECE 411.}.

ECE 611L. Optics for Scientists and Engineers Laboratory. 1 Credit.
Required laboratory for PHYS 611 or ECE 611. Ten optics experiments plus a major related optics project. Coreq: PHYS 611. Cross-listed with PHYS 611L. {Also offered for undergraduate credit - see ECE 411L.}.

ECE 613. Lasers for Scientists and Engineers. 3 Credits.
Lecture and laboratory introduction to lasers. Spontaneous and stimulated transitions, line-broadening, gain, gain saturation, optical resonators, Fabry-Perot interferometers, theory of laser oscillation, rate equations, transverse modes, coherence, and Gaussian beams. Cross-listed with PHYS 613. {Also available for undergraduate credit - See ECE 413.}.

ECE 615. Elements of Photonics. 3 Credits.
Analysis of optical systems using the matrix formulation, wave propagation in anisotropic media, electro-optic effect and laser modulation, physical origin of optical non-linearities, phase matching, optical second harmonic and parametric generation. Cross-listed with PHYS 615. {Also offered for undergraduate credit - See ECE 415.}.

ECE 617. Optical Signal Transmission. 3 Credits.
Optical signal transmission including geometric optics and modal analysis for homogeneous and inhomogeneous light guides. Systems studies including coupling, inter-symbol interference, sources, photodetectors, and modulation. Cross-listed with PHYS 617. {Also offered for undergraduate credit - see ECE 417.}.

ECE 621. Communications Circuits. 3 Credits.
Resonant circuits and tuned amplifiers, oscillators, modulators and demodulators, phase-locked loops, and power amplifiers. Analysis, design, and applications in communication systems. 3 lectures. S {Also offered for undergraduate credit - see ECE 421.}.

ECE 623. VLSI Design. 3 Credits.
Analysis and design of digital integrated circuits. Characteristics and applications of logic gates and regenerative logic circuits. 3 lectures. {Also offered for undergraduate credit - see ECE 423.}.

ECE 624. Analog VLSI. 3 Credits.
Design, analysis, and simulation of analog VLSI circuits including operational amplifiers, current mode circuits, oscillators, translinear circuits, and phase locked-loops. Design automation for analog circuits. {Also offered for undergraduate credit - see ECE 424.}.

ECE 625. Introduction to Semiconductor Devices. 3 Credits.
Properties and applications of semiconductors and solid-state electronic devices. Semiconductors, junctions, and transistors. 3 lectures. F/2 {Also offered for undergraduate credit - see ECE 425.}.

ECE 627. Packaging for Electronics. 3 Credits.
Processes and materials for packaging of electronic components and devices, including integrated circuit chips, chip packages, and board level packaged systems; boards and substrates technology; quality and reliability of electronic packages. Open to all engineering majors. Cross-listed with IME 627. {Also offered for undergraduate credit - see ECE 427.}.

ECE 629. Introduction to IC Fabrication. 3 Credits.
This course examines issues about fabrication methods and procedures. Topics will include implantation, pattern transfer and process integration. {Also offered for undergraduate credit - see ECE 429.}.

ECE 631. Power Systems. 3 Credits.
Electrical characteristics of high voltage lines. Symmetrical components, per unit system, and transformers. Matrix methods, load flow, and fault analysis. 3 lectures. F {Also offered for undergraduate credit - see ECE 431.}.

ECE 632. Computational Methods in Power Systems. 3 Credits.
Power flow, optimal power flow, state estimation, contingency analysis, unit commitment, security assessment, small signal and dynamic stability, voltage stability, emerging algorithms for blackout and vulnerability assessment in power systems. {Also offered for undergraduate credit - see ECE 432.}.

ECE 633. Power Systems Design. 3 Credits.
Unbalanced power systems, economic dispatch, transients in power systems, power system stability, power system protection. 3 lectures. S {Also offered for undergraduate credit - see ECE 433.}.

ECE 637. Power Electronics. 3 Credits.
Characteristics and modeling of power electronic devices. Rectifiers, choppers, and inverters and their applications in power supplies and motor drives. 3 lectures. F {Also offered for undergraduate credit - see ECE 437.}.

ECE 638. Electric Drives. 4 Credits.
Characteristics of loads and drive train, power converters, four quadrant ac/dc drives, DSP control, drives for special motors, applications including electric vehicles. 3 lectures, 1 two-hour laboratory. Prereq: ECE 637. S {Also offered for undergraduate credit - see ECE 438.}.

ECE 643. Communications I. 4 Credits.
Communications theory and design with an emphasis on spectral techniques. Modulation and noise effects. 3 lectures, 1 two-hour laboratory. F, S {Also offered for undergraduate credit - see ECE 443.}.

ECE 644. Applied Digital Signal Processing. 3 Credits.
Digital signal processing theory balanced with practical application. Includes design of FIR, IIR, and adaptive filters; Fast Fourier Transforms; sampling theory; implementation techniques; multi-rate processing. Emphasizes system implementation using development tools and DSP hardware. 3 lectures. F {Also offered for undergraduate credit - see ECE 444.}.

ECE 645. Communications II. 3 Credits.
Continuation of ECE 443. Digital communications systems. Optimum receivers. Information theory and coding. 2 lectures. S/2 {Also offered for undergraduate credit - see ECE 445.}.

ECE 648. Image Analysis I. 3 Credits.
Image acquisition, resolution, enhancement, restoration, and equalization. Illuminations, reflectance, and noise considerations. Segmentation, shape characterization, and object recognition. Simulation examples, computer problems, and gathering of actual scientific images via camera and computer. {Also offered for undergraduate credit - see ECE 448.}.

ECE 651. RF and Microwave Circuit Analysis and Design for Wireless Systems. 3 Credits.
This course will focus on the analysis and design of Radio Frequency (RF) and microwave circuits. In particular, circuits such as oscillators, filters, power dividers, amplifiers, mixers and modulators will be studied for wireless systems. {Also offered for undergraduate credit - see ECE 451.}.

ECE 653. Signal Integrity. 3 Credits.
Topics in system level signal integrity are presented. The construction and design of passive printed circuit cards are discussed, with computer aided design software used for analysis and class presentations. Circuit card fabrication issues and case examples of applications are discussed. F/2 {Also offered for undergraduate credit - see ECE 453.}.

ECE 655. Designing for Electromagnic Compatibility. 3 Credits.
Principles and methods concerning electronic system designs that are not sources of or susceptible to electromagnetic interference. 3 lectures. Laboratory. F/2 {Also offered for undergraduate credit - see ECE 455.}.

ECE 661. Control Systems I. 4 Credits.
Modeling and control of dynamic systems, including root-locus, Bode plots, and Nichols charts. 3 lectures, 1 two-hour laboratory. {Also offered for undergraduate credit - see ECE 461.}.

ECE 663. Modern Control. 3 Credits.
Analysis and design of controllers for linear and non-linear systems using state-space methods. Design to specifications, controllability, observability, stability, optimization and state-estimation. 3 lectures. {Also offered for undergraduate credit - see ECE 463.}.

ECE 670. Fault Tolerant Digital Design. 3 Credits.
Design and analysis of reliable digital systems through robust information coding, fault avoidance, and fault-tolerance. 3 lectures. {Also offered for undergraduate credit - see ECE 470.}.

ECE 672. Design Automation of VLSI Circuits. 3 Credits.
Electronic design automation algorithms utilized by software tools, which are used for the design automation of VLSI integrated circuits. This course will cover design steps including circuit synthesis, technology mapping, formal verification, floorplanning, placement, and routing. {Also offered for undergraduate credit - see ECE 472.}.

ECE 674. Computer Architecture. 3 Credits.
Processor operations, computer arithmetic, control mechanism, instruction sets, classification schemes, pipelining, parallel processing, hierarchical memory and memory management, I/O methods and interrupts, and interconnection buses. 3 lectures. {Also offered for undergraduate credit - see ECE 474.}.

ECE 675. Advanced Digital Design. 4 Credits.
Master advanced logic design concepts, including the design and testing of synchronous and asynchronous combinational and sequential circuits using state of the art CAD tools. 3 lectures, 1 two-hour laboratory. {Also offered for undergraduate credit - see ECE 475.}.

ECE 676. Advanced Embedded Systems. 4 Credits.
Specification, design, development, and test of modern embedded systems using a high-level programming language. 3 lectures, 1 two-hour laboratory. {Also available for undergraduate credit, See ECE 476.}.

ECE 677. Hardware Design for Machine Learning. 3 Credits.
Hardware-aware neural network (NN) design in NVidia Developer kit with OpenCV python programming. MAC design for NN and alternate neural network implementations using emerging technologies. Advanced topics in Hardware-aware neural network designs such as Binary nets, FFT-based neural nets, In-compute Memory and near-compute memory. 2 lectures, 1 two-hour laboratory. {Also offered for undergraduate credit - See ECE 477.}.

ECE 679. Formal Verification. 3 Credits.
Formal verification methods for hardware systems, such as theorem proving, property-based verification, equivalence checking, notions of correctness such as refinement, methods used in computer-aided verification including BDDs and SAT procedures. {Also offered for graduate credit - see ECE 479.}.

ECE 683. Instrumentation for Engineers. 3 Credits.
Study of instrumentation including design, fabrication, and application. F {Also offered for undergraduate credit - see ECE 483.}.

ECE 685. Biomedical Engineering. 3 Credits.
Unified study of engineering techniques and basic principles in physiological systems. Focus on membrane biophysics, biological modeling, compartmental analysis, and systems control theory. F {Also offered for undergraduate credit - see ECE 485.}.

ECE 686. Biosensing Technology. 3 Credits.
Biosensors are defined as analytical devices incorporating a biological material, a biologically derived material or a biomimic associated with or integrated within a physicochemical transducer or transducing microsystem, which may be optical, electrochemical, thermometric, piezoelectric, magnetic or micromechanical. This course provides instruction in the basic science and engineering concepts required to understand the design and application of biosensors. This module serves as an introduction to some of the biosensors and measurement techniques. Prereq: Graduate standing. {Also available for undergraduate credit - see ECE 486.}.

ECE 687. Cardiovascular Engineering. 3 Credits.
This course includes the application of engineering techniques to cardiovascular physiology and medicine. Basic cardiac and vascular physiology will be presented, modeling techniques will be examined. Instrumentation, measurement theory, and assist devices will be discussed. S {Also offered for undergraduate credit - see ECE 487.}.

ECE 688. Cardiovascular Engineering II. 3 Credits.
Analysis, design, and research methods related to modeling and simulating the cardiovascular system. Prereq: ECE 687. {Also offered for undergraduate credit - see ECE 488.}.

ECE 690. Graduate Seminar. 1-3 Credits.

ECE 695. Field Experience. 1-15 Credits.

ECE 696. Special Topics. 1-5 Credits.

ECE 701. Advanaced Engineering Problem Solving. 3 Credits.
Application of advanced mathematical and computational methods to engineering problems. 3 lectures. S.

ECE 702. Advanced Research Topics. 1 Credit.
Prepare the student in finding a major adviser; defining the research questions or objectives; beginning a literature search; learning how to prepare a manuscript and/or grant application with their major adviser. F.

ECE 703. Advanced Teaching and Classroom Topics. 1 Credit.
To help prepare the Ph.D. student for the challenge of teaching in a classroom. F.

ECE 705. Stochastic Processes. 3 Credits.
Random variables, probability bounds, random vectors, random sequences, stochastic processes, and statistical signal processing.

ECE 713. Introduction to Lab-on-a-Chip Technology. 3 Credits.
This course introduces the fundamentals of Lab-on-a-chip technology. It also provides a comprehensive picture of instruments, tools and techniques used in various aspects of Lab-on-a-chip technology. Finally, some applications in biomedical engineering will be discussed.

ECE 721. Integrated Circuits. 3 Credits.
Introduction to CMOS circuits. Circuit characterization and performance estimation. CMOS circuit and logic design, CMOS testing. CMOS subsystem design. 3 lectures. Prereq: ECE 623.

ECE 722. Wireless IC Design. 3 Credits.
Basic concepts of wireless IC design. Various radio transceiver architectures and its application. Design of CMOS radio transceiver circuit blocks. Hands-on-experience on IC design and layout using industry-based chip design software Cadence. Prereq: ECE 621.

ECE 723. Advanced Electronics. 3 Credits.
Characteristics and detailed modeling of operational amplifiers. Applications to waveform generation, analog multiplication, modulation, and data conversion. IC and special amplifiers. 3 lectures. Prereq: ECE 621. (alternate years).

ECE 726. Advanced VLSI Design. 3 Credits.
This course covers state-of-the-art design techniques for VLSI at device, circuit, architecture, and application levels. Prereq: ECE 423 or ECE 623.

ECE 731. Power System Protection. 3 Credits.
Power system protective relaying. Generator, transformer, line, bus, motor protection. 3 lectures. Coreq: ECE 633. S.

ECE 733. Power Distribution. 3 Credits.
Power distribution systems. Lines and transformers, characteristics of loads, voltage drops and corrective measures, lightning protection. Fault analysis, fuses, reclosers, sectionalizers. Power system harmonics and power quality. 3 lectures. Coreq: ECE 631. F.

ECE 734. Modeling and Control of High Voltage Direct Current (HVDC) Systems. 3 Credits.
The course covers fundamentals of modeling, analysis and control of LCC and VSC HVDC systems. Applications integrating renewable energy will also be studied. Prereq: ECE 631.

ECE 737. Advanced Power Electronics. 3 Credits.
The course teaches the characteristics and detailed design of power semiconductors, power conversion topologies and controls, passive component design and selection, and advanced control strategies for DC-DC converters and DC-AC Inverters. 3 lectures Prereq: ECE 637.

ECE 741. Signal Processing I. 3 Credits.
Analysis and design of discrete- and continuous time signals and systems. Advanced treatment of transform techniques and Fourier analysis. Classical filter design techniques. Fast Fourier transform algorithms and applications. 3 lectures. Prereq: ECE 643.

ECE 743. Signal Processing II. 3 Credits.
Discrete-time Wiener and Kalman filtering. Least squares signal processing and filter design. Spectral analysis. Adaptive signal processing. 3 lectures. Prereq: ECE 741. S.

ECE 745. Statistical Communications. 3 Credits.
Advanced topics in communications theory including detection theory, estimation theory, and information theory. 3 lectures. Prereq: ECE 643. S.

ECE 748. Elements of Information Theory. 3 Credits.
This course will cover: entropy, asymptotic equipartition property, data compression, channel capacity, differential entropy, the Gaussian channel, an introduction to rate distortion theory and network information theory.

ECE 749. Wireless Communication. 3 Credits.
Wireless channel model, design of transmission and reception techniques for wireless communication systems and their performance analysis.

ECE 751. Electromagnetic Theory and Applictions. 3 Credits.
Theory of radiation, antenna characteristics, complex waves, potential functions and spectral domain methods for wave guides and cavities, and dispersive media. 3 lectures. S/2.

ECE 755. Advanced Topics in Electromagnetics. 3 Credits.
Topics of current interest in electromagnetics, microwaves, and optics. 3 lectures. Prereq: ECE 751. S/2.

ECE 761. Advanced Control Theory I. 3 Credits.
State variable formulation of the control problem; system identification. Introduction to adaptive, distributed, multivariable, nonlinear, optimal, and stochastic control.

ECE 763. Advanced Control Theory II. 3 Credits.
State variable formulation of the control problem; system identification. Introduction to adaptive, distributed, multivariable, nonlinear, optimal, and stochastic control. Prereq: ECE 761.

ECE 772. Low Power Circuit and System Design. 3 Credits.
This course will cover state-of-the-art design techniques for low power digital circuits and systems at device, circuit, architecture, system, and application levels.

ECE 775. Hardware For Cryptography. 3 Credits.
This course covers the mathematical background, modern cryptographic techniques like block ciphers, hash functions and public-key cryptosystems. Hardware and embedded implementations of cryptosystems and recent research in hardward implementation are also covered. Prereq: CSCI 669.

ECE 776. Software and Hardware for Cloud Computing. 3 Credits.
The course will focus on the architectural components of cloud computing systems with particular emphasis on service delivery models and management of cloud environment and services. Prereq: ECE 774.

ECE 777. System Level Design and Automation. 3 Credits.
Background, useful abstractions and needed techniques for system-level modeling, performance analysis, synthesis and optimization. Emphasis is on both computation and communication aspects involved in the Systems-On-Chip design of embedded applications.

ECE 778. Computer Networks. 3 Credits.
Examination of computer networks using the ISO-OSI model as a framework. Exploration of practical and theoretical issues in modems, codes, error, impairments, modulation, protocols, and interfaces. 3 lectures. (alternate years).

ECE 787. Advanced Cardiovascular Engineering III. 3 Credits.
Advanced research topics in multi-scale cardiac modeling such as vetriculo-arterial coupling, organ-level characterization, tissue characterization, cellular properties, and sub-cellular processes culminating in a grant proposal. Prereq: ECE 687 and ECE 688.

ECE 788. Advanced Cardiovascular Engineering IV. 3 Credits.
Advanced research topics in multi-scale cardiac modeling such as ventriculo-arterial coupling, organ-level characterization, tissue characterization, cellular properties, and sub-cellular processes culminating in a research journal manuscript or conference proceeding. Prereq: ECE 787.

ECE 790. Graduate Seminar. 1-3 Credits.

ECE 791. Temporary/Trial Topics. 1-5 Credits.

ECE 793. Individual Study/Tutorial. 1-5 Credits.

ECE 795. Field Experience. 1-15 Credits.

ECE 796. Special Topics. 1-5 Credits.

ECE 797. Master's Paper. 1-3 Credits.

ECE 798. Master's Thesis. 1-10 Credits.

ECE 801. Big Data and Cloud Computing. 3 Credits.
The course will focus on the state-of-the-art cloud infrastructure with primary emphasis on manipulating, storing, and analyzing big data. Prereq: ECE 776.

ECE 802. High Performance Computing in the Cloud. 3 Credits.
The course will focus on a compelling vision of seamless scaling of computational resources in the cloud computing paradigm to achieve high performance. Prereq: ECE 776.

ECE 892. Graduate Teaching Experience. 1-6 Credits.

ECE 893. Individual Study. 1-5 Credits.

ECE 898. Continuing Enrollment. 1-9 Credits.
For graduate students who have completed all necessary credits of course work including thesis (798) and dissertation (899) on their approved Plan of Study, but who have not yet completed and submitted their thesis or dissertation. This course does not count towards the credit requirements for the degree and is not financial aid eligible. Department consent required to enroll.

ECE 899. Doctoral Dissertation. 1-15 Credits.