Electrical and Computer Engineering

Electrical Engineering

The Department of Electrical and Computer Engineering serves the community, the state and the nation by educating engineers, expanding knowledge and developing new tools for solving complex technological problems. The department's graduate programs offer students with backgrounds in electrical engineering or related areas unusual opportunities to specialize in advanced phases of electrical engineering. In addition to more than 30 full-time faculty members devoted to teaching and research, students are taught by adjunct professors from industry who offer specialty courses in their area of expertise and serve on thesis and dissertation committees.

The master's degree programs provide state-of-the-art training at advanced levels in areas of technical specialization, including faculty-supervised research. Students in the doctoral program conduct significant original research in areas of interest to department members. Students also have opportunities to conduct thesis research at industrial sites, hospitals, biomedical engineering facilities, and university centers and departments.

Master of Science in Electrical Engineering

A program for students with an undergraduate degree in engineering who wish either to specialize in an advanced phase of electrical engineering or prepare for a more advanced degree.

Admission Requirements

Applicants are expected to have undergraduate backgrounds in physics, mathematics (through differential equations and vector analysis), electrical networks and devices, electronics, analysis and design methods, transients, electromagnetic fields, and appropriate laboratory work in some of these areas. GRE scores must be submitted. International students must also achieve a minimum TOEFL score of 550 (213 computer-based). For further information, see the Admissions section in this catalog.

Graduate Certificate Program

A 12-credit graduate certificate in Telecommunications Networking is available as a step toward this degree. See **Graduate Certificates** in the Degree Programs section of this catalog. For further information, call the Associate Vice President of Continuing and Distance Education, Division of Continuing Professional Education, 1 (800) 624-9850 or (973) 596-3060; e-mail cpe@njit.edu

Doctor of Philosophy in Electrical Engineering

This is a program for superior students with master's degrees in electrical engineering or allied fields who wish to conduct advanced research in an area of electrical engineering.

Exceptional Candidates with a Bachelor of Science in Electrical Engineering

Highly qualified students with bachelor's degrees in electrical engineering may be accepted directly into the doctoral program. Contact the doctoral program coordinator for further information.

Admission Requirements

Applicants are expected to have a broad background in engineering, mathematics, physics, and computer science. At least half of undergraduate course work should have been in the physical sciences or similar fields. Doctoral students should have majored in electrical engineering or related field, with course work at the master's level in mathematics, physics and/or computer science. In addition, students are expected to be proficient in computer programming. A minimum master's GPA of 3.5 on a 4.0 scale, or equivalent, is required for admission. GRE scores must be submitted. International students must also achieve a minimum TOEFL score of 550 (213 computer-based).

Students who lack an appropriate background will be required to take additional courses that cannot be applied as degree credits.

Computer Engineering

Focus on interdisciplinary course work and research provides students enrolled in the M.S. and Ph.D. in Computer Engineering programs with an advanced background in both the hardware and software aspects of computing.

The master's program prepares computer engineers to successfully make the hardware-software design trade-offs inherent to computing today. The rapid development of computer hardware and software in the last decade has created a demand for engineers who are not only knowledgeable in both these areas, but who also understand their interaction. The fields of embedded computer system design and computer networks are based squarely on this knowledge.

The doctoral program is designed for superior students with a master's degree in computer engineering, computer science, electrical engineering, or other related fields, who wish to pursue advanced research in the area of computer engineering. The master's and doctoral programs emphasize computer architecture and systems, computer networking, intelligent systems, microprocessor-based systems, and VLSI system design.

Master of Science in Computer Engineering

This program prepares its graduates to successfully handle problems requiring in-depth knowledge of both computer hardware and software, and more important, their interaction. Students may concentrate in microprocessor-based systems, parallel computing systems, computer networking, VLSI system design, or machine vision systems. All applicants must submit GRE scores. International students must achieve a minimum TOEFL score of 550 (pencil and paper) and (213 computer-based).

Admission Requirements

Applicants are expected to have an undergraduate education in engineering or computer science. Applicants with baccalaureate degrees in areas other than computer engineering may be admitted and required to complete a bridge program. Those with undergraduate degrees in other fields should consult the MSCOE Program Advisor for bridge requirements. Bridge courses do not count toward degree requirements.

Graduate Certificate Program

A 12-credit graduate certificate in Information Assurance is available as a step toward this degree. Please see **Graduate Certificates** in this catalog for further information. For more information about continuing and distance education, please contact the Division of Continuing Professional Education, 1-800-624-9850 or 973-596-3060; email: cpe@njit.edu.

Doctor of Philosophy in Computer Engineering

This program is intended for superior students with a master's degree in computer engineering, computer science, electrical engineering, or other related fields, who wish to pursue advanced research in computer engineering. The program emphasizes the following areas: computer architecture and systems, computer networking, intelligent systems, microprocessor-based systems, and VLSI systems design.

Admission Requirements

Applicants are expected to have a master's degree in computer engineering, computer science, electrical engineering, or other related fields. Students who lack an appropriate background may be admitted and required to take bridge courses that cannot be applied as degree credits.

Students must demonstrate superior academic background in engineering, mathematics, and physical science; skills in programming; and proficiency in major areas of computer engineering and science. A minimum master's GPA of 3.5 on a 4.0 scale, or equivalent, is required for admission. GRE scores must be submitted. International students must also achieve a minimum TOEFL score of 550 (213 computer-based).

Superior undergraduate students may apply to be admitted directly into the Ph.D. program. Such an accelerated program requires a minimum entrance GPA of 3.5 and an interview with the Electrical and Computer Engineering Department Graduate Affairs Committee.

Internet Engineering

The objective of the master of science in internet engineering program is to educate students in the field of internet engineering, with emphasis on computer internetworking and relevant applications.

Admission Requirements

Applicants should have an undergraduate degree in Computer Engineering, Electrical Engineering or other relevant discipline from an accredited institution (or its equivalent). All applicants must submit scores on the Graduate Record Examinations (GRE) verbal, quantitative, and analytical aptitude tests. International students must also achieve a minimum TOEFL score of 550 (pencil and paper) and 213 (computer-based). Applicants with undergraduate degrees in computer science, computer engineering or electrical engineering from an accredited institution are expected to have a GPA of at least 3.0 on a 4.0 scale. These students should have taken ECE 321 Random Signals and Noise), or another equivalent course; ECE 333 Signals and Systems; and proficiency in C++ programming.

Power and Energy Systems (PES)

The master of science in power and energy systems is a program for students with an undergraduate degree in engineering who wish either to specialize in an advanced phase of electrical power engineering and energy systems to prepare for a more advanced degree.

Admission Requirements

Applicants are expected to have undergraduate backgrounds in physics, mathematics (through differential equations and vector analysis), electrical networks and devices, electronics, analysis and design methods, transients, electromagnetic fields, and appropriate laboratory work in some of these areas. GRE scores must be submitted. International students must also achieve a minimum TOEFL score of 79 out 120 (or 550 in the old score system). For further information, see the **Admissions** section in this catalog.

Graduate Certificate Program

A 12-credit graduate certificate in Power and Energy Systems is available and can be taken as a step toward this degree. See **Graduate Certificates** in the Degree Programs section of this catalog. For further information, call the Associate Vice President of Continuing and Distance Education, Division of Continuing Professional Education, 1 (800) 624-9850 or (973) 596-3060; e-mail cpe@njit.edu.

Telecommunications

Telecommunications is one of the most rapidly growing fields in engineering. Telecommunications specialization also is rapidly becoming necessary in such diverse fields as banking, reservation systems, office information systems, corporate networks, and the Internet. Rapid technological progress in gigabit optical networks, multimedia communications, and wireless network access, make the future of the field very exciting.

Master of Science in Telecommunications

The objective of this program is to educate individuals in one or more telecommunication specializations.

Admission Requirements

Applicants are expected to have an undergraduate degree in computer science, computer engineering or electrical engineering from an accredited institution (or its equivalent) with a minimum GPA of 3.0 on a 4.0 scale. These students should have taken CS 333 Introduction to UNIX Operating Systems, ECE 321 Random Signals and Noise and ECE 333 Signals and Systems (or their equivalents). Students without this course work will be required to complete a bridge program. Applicants having degrees in other fields may be considered for admission on an individual basis and required to complete a bridge program. GRE scores must be submitted. International students must also achieve a minimum TOEFL score of 550 (pencil and paper) and 213 (computer-based).

Graduate Certificate Program

A 12-credit graduate certificate in Telecommunications Networking is available as a step toward this degree. See "**Graduate Certificates**" in this catalog. For further information about extension programs and graduate certificates, call the associate vice president of continuing and distance education, Division of Continuing Professional Education, 1 (800) 624-9850 or (973) 596-3060; e-mail cpe@njit.edu

NJIT Faculty

A

Abdi, Ali, Professor

Akansu, Ali N., Professor

Ansari, Nirwan, Professor

B

Bar-Ness, Yeheskel, Distinguished Professor Emeritus

C

Carpinelli, John D., Professor

Carr, William N., Professor Emeritus

Cornely, Roy H., Professor Emeritus

D

Dhawan, Atam P., Distinguished Professor

F

Feknous, Mohammed, University Lecturer

Frank, Joseph Associate Professor Emeritus

Friedland, Bernard, Distinguished Professor

G

Ge, Hongya, Associate Professor

Grebel, Haim, Professor

H

Haddad, Richard A., Professor Emeritus

Haimovich, Alexander M., Professor

Hou, Sui-Hoi Edwin, Associate Professor

Hubbi, Walid, Associate Professor

K

Kam, Moshe, Professor and Dean of NCE

Khreishah, Abdallah, Assistant Professor

Klapper, Jacob, Professor Emeritus

Kliewer, Joerg, Associate Professor

Ko, Dong-Kyun, Assistant Professor

L

Liu, Qing, Assistant Professor

Liu, Xuan, Assistant Professor

M

Manzhura, Oksana Yu, University Lecturer

Meyer, Andrew U., Professor Emeritus

Misra, Durgamadhab, Professor

N

Nguyen, Hieu, Assistant Professor

R

Raj, Ratna, University Lecturer

Rojas-Cessa, Roberto, Associate Professor

Rosenstark, Solomon, Professor Emeritus

S

Savir, Jacob, Distinguished Professor

Shi, Yun-Qing, Professor

Simeone, Osvaldo, Associate Professor

Sohn, Kenneth S., Professor Emeritus

Sosnowski, Marek, Professor

T

Tsybeskov, Leonid, Professor and Chair

W

Wang, Cong, Assistant Professor

Z

Zhou, Mengchu, Distinguished Professor

Ziavras, Sotirios G., Professor

Programs

- Computer Engineering - M.S. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/computer-ms/)
- Electrical Engineering - M.S. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/electrical-ms/)
- Power and Energy Systems - M.S. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/power-energy-systems-ms/)
- Telecommunications - M.S. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/telecommunications-ms/)

Programs

- Computer Engineering - Ph.D. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/computer-phd/)
- Electrical Engineering - Ph.D. (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/electrical-phd/)

Programs

- Power Systems Engineering (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/power-systems-engineering-cert/)
- Wind Power System Operation & Maintenance (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/wind-power-system-operation-and-maintenance-cert/)
- Wind Power Management (http://catalog.njit.edu/graduate/newark-college-engineering/electrical-computer/wind-power-management-cert/)

Electrical and Computer Engineering Courses

ECE 590. Graduate Co-op Work Experience I. 1 credit, 1 contact hour.
Restriction: permission from Department of Electrical and Computer Engineering and Division of Career Development Services. Cooperative education/ internship providing on-the-job reinforcement of academic programs in electrical and computer engineering. Assignments and projects are developed by the co-op office in consultation with the electrical and computer engineering department. Work assignments are related to student's major and are evaluated by faculty coordinators in the ECE department. Credits for this course may not be used to fulfill any electrical or computer engineering degree requirement.

ECE 591. Graduate Co-op Work Experience II. 1 credit, 1 contact hour.
Prerequisites: ECE 590 and permission from Department of Electrical and Computer Engineering and Division of Career Development Services. See ECE 590 course description. Credits for this course may not be used to fulfill any electrical or computer engineering degree requirement.

ECE 592. Graduate Co-op Work Experience III. 1 credit, 1 contact hour.
Restriction: graduate standing and permission from Department of Electrical and Computer Engineering and Division of Career Development Services. See ECE 590 course description. Credits for this course may not be used to fulfill any electrical or computer engineering degree requirement.

ECE 593. Graduate Co-op Work Experience IV. 0 credits, 0 contact hours.
Restriction: One immediately prior 3-credit registration for graduate co-op work experience with the same employer. Requires approval of departmental co-op advisor and the Division of Career Development Services. Must have accompanying registration in a minimum of 3 credits of course work.

ECE 601. Linear Systems. 3 credits, 3 contact hours.
Methods of linear-system analysis, in both time and frequency domains, are studied. Techniques used in the study of continuous and discrete systems include state-variable representation, matrices, Fourier transforms, LaPlace transforms, inversion theorems, sampling theory, discrete and fast Fourier transforms, and Z-transforms. Computer simulation of linear systems is used, and, where feasible, computer solutions are obtained.

ECE 605. Discrete Event Dynamic Systems. 3 credits, 3 contact hours.
Covers the theory of discrete event dynamic systems with applications in modeling, control, analysis, validation, simulation, and performance evaluation of computer systems, flexible manufacturing systems, robotic systems, intelligent supervisory control systems, and communication networks. Emphasis on Petri net and automation based approaches.

ECE 610. Power System Steady-State Analysis. 3 credits, 3 contact hours.
Steady-state analysis of power system networks, particularly real and reactive power flows under normal conditions and current flows under faulty conditions. Symmetrical components and digital solutions are emphasized. An undergraduate background in Electrical Engineering or Mechanical Engineering is necessary.

ECE 611. Transients in Power Systems. 3 credits, 3 contact hours.
Prerequisite: ECE 610. Transient performance of power systems with lumped properties, interruption of arcs, restriking voltage, re-ignition inertia effects, switching of rotational systems, magnetic saturation in stationary networks, harmonic oscillations, saturated systems, transient performance of synchronous machines.

ECE 612. Computer Methods Applied to Power Systems. 3 credits, 3 contact hours.
Digital computer techniques proven successful in the solution of power system problems, particularly in the electric utility industry. Emphasis on short-circuit, load flow, and transient stability problems. Matrix sparsity is considered. Prior basic trainings on programming are necessary.

ECE 613. Protection of Power Systems. 3 credits, 3 contact hours.
Prerequisite: ECE 610 or equivalent Coils, condensers, and resistors as protective devices; fundamental principles of protective relaying; relay operating characteristics; power and current directional relays; differential relays; distance and wire pilot relays; heating and harmonic effects; and Computer-based protective device coordination.

ECE 616. Power Electronics. 3 credits, 3 contact hours.
Principles of thyristor devices, dynamic characteristics of choppers, commutation, protection, voltage-fed and current-fed inverter drives, cycloconverters, pulse width modulation, phase control, and microcomputer control, with case studies. An undergraduate background in Electrical Engineering or similar is necessary.

ECE 617. Economic Control of Interconnected Power Systems. 3 credits, 3 contact hours.
Economic Control of Interconnected Power Systems: Advanced techniques for operating power systems in the most economic manner while meeting various network constraints; economic dispatch, penalty factors, optimal power flow, short-term electricity markets and locational marginal prices will be studied.

ECE 618. Photovoltaic Semiconductors and Renewable Energy. 3 credits, 3 contact hours.
This course introduces renewable energy systems. It covers the fundamental concepts of energy and radiation with specific solar energy applications and photovoltaics, electrical energy storage systems, and thermal energy and storage. The second part covers the basic science of wind energy systems and their electrical sytem designs. The third part covers the bioenergy systems from resources to final products and conversion technologies. It finally introduces other promising energy sources.

ECE 619. Intelligent Sensing for Smart Grid and Smart City. 3 credits, 3 contact hours.
This course introduces the fundamentals and applications of intelligent sensing technology to smart grid and smart city. The course covers the fundamental sensing principles, types and selection of sensors including electromagnetic field sensors, amplifiers and bridge circuits, and sensing system architecture. Estimation and evaluation of sensor calibration and their responses by using finite element method, sensor noise and shielding design will be addressed. Signal analysis techniques such as wavelet analysis and sensor fusion will be discussed. Anomaly detection, fault classification and prediction and decision making on sensor data by machine learning, and the applications of electromagnetic sensing in power systems will be covered. Advanced sensor applications topics in IoT, smart grid and smart city will also be included. Prior undergraduate trainings in basic electromagnetics and circuit theories are necessary.

ECE 620. Electromagnetic Field Theory. 3 credits, 3 contact hours.
Maxwell's equations, boundary conditions and formulation of potentials. LaPlace and Poisson equations for electrostatic and magnetostatic problems and the method of images. Dielectric and magnetic materials, force and energy concepts. Quasi-static and time varying fields, plane, cylindrical and spherical waves. Green's functions, transmission lines. Prior undergraduate trainings in electromagnetic field theories are necessary.

ECE 622. Wave Propagation. 3 credits, 3 contact hours.
Prerequisite: ECE 620 or equivalent. Fundamentals of electromagnetics; radiation and scattering; Green's functions; integral equations; numerical methods; ray optics and asymptotics.

ECE 624. Optical Engineering. 3 credits, 3 contact hours.
This course covers basic optical concepts, emphasizing those common to many optical instruments, such as light sources and their characteristics, polarization, coherence, and interferometry. The course introduces CAD tools for lenses, optical filters, and instrument design. The course also focuses on topics concerning optical systems, such as flat panel displays and micromechanical optical systems.

ECE 625. Fiber and Integrated Optics. 3 credits, 3 contact hours.
Prerequisite: undergraduate electromagnetic field theory and solid-state circuits. Planar dielectric waveguides, step and graded index fibers and dispersion in fibers. The p-n junction and heterostructures, light emitting diodes and semiconductor lasers, p-i-n and avalanche photodetectors, optical transmitter and receiver designs, optical fiber communication system design concepts.

ECE 626. Optoelectronics - Nonlinear Modulators for Optical Communication. 3 credits, 3 contact hours.
Optical propagation in anisotropic materials, polarization, birefringence and periodic media. Concepts of electro-optics and acousto-optic devices, optical modulators, switches, active filters for optical communication and optical processing. Prior undergraduate trainings on electromagnetic field theories and solid-state circuits are necessary.

ECE 628. Power Grid Modernization. 3 credits, 3 contact hours.
This course provides a comprehensive exploration of the modernization of the power grid, focusing on the evolving infrastructure and technologies driving the next generation of electrical systems. The course delves into power transformers, substations, distribution automation, advanced metering infrastructure, and the resilience challenges posed by climate change, such as fire and storm damage. Emphasis will be placed on the integration of renewable energy sources like solar and wind, energy storage systems, and electric vehicles, as well as the role of intelligent substations, reliability, and resiliency improvements through smart grid technologies. Other key topics include power system planning, load forecasting, real and reactive power transfer, cybersecurity, system protection, and the development of microgrids and virtual power plants. By the end of the course, students will gain a comprehensive understanding of the critical elements driving power grid modernization.

ECE 629. Power System Modeling. 3 credits, 3 contact hours.
This graduate-level course provides an in-depth exploration of power system modeling and simulation, emphasizing hands-on experience with essential industry-standard software tools. Designed for students interested in careers as power grid planners, operators, or researchers, the course prepares students to address key challenges in renewable integration, energy storage, and power system stability. Students will gain expertise in specialized software tools. One of the tools is commonly used for steady-state analysis and grid planning tasks. It can be used for studying power flow, contingency analysis, and voltage stability with focus on grid operations and planning, gaining insight into grid planning and decision-making processes. Another tool specializes in dynamic simulations and is used for studying the transient stability and detailed behavior of power system components, particularly in scenarios involving power electronics and renewable energy integration. Students can apply it in operational studies, where understanding the system's response to disturbances or the integration of renewable sources (like wind or solar) is critical. A final project will involve constructing and analyzing a renewable project model, incorporating industry standards and producing a comprehensive report based on simulated results.

ECE 630. Microwave Engineering. 3 credits, 3 contact hours.
Review of transmission line theory and the Smith chart; scattering matrix representation, LC and microstrip matching networks; signal flow graph analysis; micro-wave transistor amplifier design, which includes power gain, stability, noise figure circles; oscillator design. Prior undergraduate trainings in electromagnetic field theories are necessary.

ECE 632. Antenna Theory. 3 credits, 3 contact hours.
Fundamentals of electromagnetic field theory; far field approximation, antenna characteristics (gain, impedance, pattern, etc.); elementary antenna types (dipoles, loops, etc.), antenna array theory, wire antennas; broadband antennas. Prior undergraduate trainings in electromagnetic field theories are necessary.

ECE 636. Computer Networking Laboratory. 3 credits, 3 contact hours.
This course provides students with hands on training regarding the design, troubleshooting, modeling and evaluation of computer networks. In this course, students are going to experiment in a real test-bed networking environment, and learn about network design and troubleshooting topics and tools such as: network addressing, Address Resolution Protocol (ARP), basic troubleshooting tools (e.g. ping, ICMP), IP routing (e,g, RIP), route discovery (e.g. traceroute), TCP and UDP, IP fragmentation and many others. Student will also be introduced to the network modeling and simulation, and they will have the opportunity to build some simple networking models using the OPNET modeling tool and perform simulations that will help them evaluate their design approaches and expected network performance.

ECE 637. Internet Protocols and their Evolution with Artificial Intelligence. 3 credits, 3 contact hours.
The course analyzes the protocols that govern the Internet and discusses their evolution motivated by a variety of emerging networks and applications. The course also explores how these protocols adopt artificial intelligence (AI), such as machine learning algorithms, used to improve performance across the different layers of the protocol stack, with applications in areas such as security. Students will be also immersed in principles of protocol design through practical examples.

ECE 638. Network Management and Security. 3 credits, 3 contact hours.
Prerequisites: ECE 683 or CS 652, and ECE 637 or CS 656. Thorough introduction to current network management technology and techniques, and emerging network management standards. In-depth study of the existing network security technology and the various practical techniques that have been implemented for protecting data from disclosure, for guaranteeing authenticity of messages, and from protecting systems for network-based attacks. SNMP family of standards including SNMP, SNMPv2, and RMON (Remote Monitoring), OSI systems management. Various types of security attacks (such as intruders, viruses, and worms), Conventional Encryption and Public Key Cryptology. Various security services and standards (such as Kerberos, Digital Signature Standard, Pretty Good Privacy, SNMPv2 security facility). Same as CIS 696.

ECE 639. Principles of Broadband Networks. 3 credits, 3 contact hours.
Prerequisites: ECE 673, ECE 683 or CS 652 or equivalent. This course covers fundamental concepts of broadband networks. Topics include Broadband ISDN, Switching Techniques, ATM, SONET/SDH, Congestion Control, High-Speed Switching Architectures, Traffic Modeling of Broadband Services, Admission Control, Traffic Scheduling, IP/ATM Convergence, QoS Provisioning in IP Networks, and Optical Networks.

ECE 640. Digital Signal and Data Processing. 3 credits, 3 contact hours.
Prerequisite: ECE 601 or equivalent. The fundamentals of signal theory and transforms are introduced in this course. The representation of signals in the time and complex domains is covered. Z-transform is presented and Laplace transform to Z-transform mapping techniques are studied. Fourier analysis tools for analog and discrete-time signals are developed and tied with popular engineering applications. The subspace methods and eigendecomposition are studied. Their big data applications are presented. Basic design techniques to design digital filters are covered in this course.

ECE 641. Laboratory for High Performance Digital Signal Processing. 3 credits, 3 contact hours.

ECE 642. Introduction to Communication Systems: Evolution to 5G and Beyond. 3 credits, 3 contact hours.
Corequisite: ECE 673. Principles of communication theory applied to the representation and transmission of information, starting from analog communication to digital communication and ending at modern cellular systems as 5G and beyond. Topics include analysis of deterministic and random signals, amplitude modulation, angle modulation, sampling, quantization, geometric representation of signals, digital modulation as QAM, PSK, and OFDM, error probability, matched filter and correlation receivers, and the performance analysis of communication systems.

ECE 643. Digital Image Processing I. 3 credits, 3 contact hours.
Prerequisite: ECE 601. Introductory course in digital image processing. Topics include image models, digitization and quantization, image enhancement in spatial and frequency domains, image restoration, image segmentation and analysis.

ECE 644. Wireless Communications: Fundamentals to 5G. 3 credits, 3 contact hours.
This course is focused on the technical challenges and solutions to physical and link layer design of wireless communication systems. Course topics include characterization of the wireless channel, the cellular concept, digital modulation techniques, spread spectrum, multiple access techniques including CDMA and OFDM, diversity techniques. Advanced techniques such as LTE, MIMO, 5G NR technologies are introduced. Matlab is used for examples and assignments. Prior undergraduate trainings in Random Signals and Noise (ECE 321) or Probability and Statistics (MATH 333) are necessary.

ECE 645. Design of Wireless Networks: 5G Architecture and Services. 3 credits, 3 contact hours.
This course focuses on the upper-level design of wireless networks, especially the 5G architectures that intend to provide a common platform for everything connected to everything. It also introduces optional architectures in 5G to support services such as internet of things (IoT), autonomous vehicles, big data, mobile positioning, etc. The course prepares students to be constructive in engineering design in the new environment of 5G wireless communications. Upon completion of the course, students are expected to have a solid understanding of the capabilities and limitations of 5G networks, as well as the knowledge necessary to design, implement, and troubleshoot 5G systems from system engineering point of view. In addition, they would be prepared to conduct research on the current and future trends in 5G technology. To take this course, basic knowledge is required on probability and statistics, or trainings on random signals and noises.

ECE 650. Electronic Circuits. 3 credits, 3 contact hours.
Prerequisite: senior undergraduate level semiconductor circuits. Methods of analysis and design of linear and digital semiconductor circuits are studied. Topics include low and high frequency models, passive and active biasing techniques, I-C analysis and design, op-amp circuits, and active filters.

ECE 651. Wind Power Transmission and Grid Interconnection. 3 credits, 3 contact hours.
Restrictions: Students are required to electrical engineering background or related engineering or physical science backgrounds. This course aims to give the students advanced competences for the connection to the onshore power grid and the integration of offshore wind power. It involves offshore grid technology, operation principles, and the control of power converters and grids. It will provide knowledge about the role of wind power in the overall grid operation. The students will learn technical design aspects as well as related current economic conditions, including various regulation aspects of wind power and its influence on overall energy system operation. It will include an introduction of offshore wind power status and trends, electrical design aspects in offshore wind farms, grid connection and integration of offshore wind power, grid codes, dynamic models for offshore wind power plants, converter modelling and converter control.

ECE 652. HVDC Design, Operation and Maintenance. 3 credits, 3 contact hours.
Restrictions: Students are required to have electrical engineering background or related engineering or physical science backgrounds. This course covers the design, operation, and maintenance of HVDC (High-Voltage Direct Current) transmitted wind power. The course starts with a short review of the challenges that the transmission of offshore wind power faces. Next it is discussed how HVDC components are designed and what their main properties are. Subsequent lectures focus on the use of HVDC transmission as a technical solution addressing the issues described above. Basic mathematical models and control strategies are presented to analyze the impact of these devices on power system stability. Operating procedures and maintenance guidelines of the various HDVC transmission components are studied based on systems that are currently being deployed in offshore wind farms.

ECE 653. Micro/Nanotechnologies for Interacing Live Cells. 3 credits, 3 contact hours.
In this course, we will study technologies and tools available for interfacing live cells from a sub-cellular, single-cell, and multi-cellular (tissue models) approach. We will introduce key concepts of the biology of cells and tissues and will explore the technologies (micro-/nanotechnologies) and tools (sensors and actuators) available for the investigation of cell and tissue biology. Same as BME 653.

ECE 654. US Offshore Renewable Energy Policy. 3 credits, 3 contact hours.
This course will examine the statutory and regulatory frameworks that govern offshore wind farm leases and the permitting requirements associated with project development and construction. It will provide an overview of the legal regimes relevant to offshore wind, including property rights, climate change and energy, marine environmental protection, and maritime safety and security. Students will obtain a firm understanding of the permitting framework for offshore wind projects and the potential legal challenges associated with their development, construction, and finance. The course aims to equip students with an enhanced framework for evaluating US offshore energy and environmental policies that goes beyond traditional economic and regulatory perspectives.

ECE 656. Power System Dynamics. 3 credits, 3 contact hours.
Restrictions: Students are required to have electrical engineering background or related engineering or physical science backgrounds. The aim of this course is to provide students with knowledge in the analysis of power system dynamics and stability, focusing on practical applications in the energy market. The course presents power system stability, representation of synchronous machines, AC transmission modeling in stability studies, static and dynamic load models, steam and hydro turbines, governing systems, HVDC systems and their representation in stability studies, small-signal stability, small-signal stability of a single machine and multimachine systems, transient stability, simulation of power system dynamic response, direct method of transient stability analysis, voltage stability and voltage collapse, wide-area monitoring, and the impact of wind integration on power system dynamics. Additionally, the course explores the operation of wind energy in the power market to provide a comprehensive understanding of the evolving energy landscape.

ECE 657. Semiconductor Devices. 3 credits, 3 contact hours.
Fundamental principles of solid state materials necessary for understanding semiconductor devices. Topics include crystal structure; energy bands; electron and hole generation, and transport phenomena; generation and recombination processes, and high field effects. P-N junction diode, metal semiconductor contact, and bipolar and metal oxide semiconductor transistors, including switching phenomena and circuit models. Introduction to: photonic devices~light emitting diodes, semiconductor lasers, photodetectors, and solar cells; microwave devices~tunnel and IMPATT diodes, transferred electron devices, and charge-coupled capacitors.

ECE 658. VLSI Design I. 3 credits, 3 contact hours.
Analysis and design of digital integrated circuits; basic building blocks and dependence on circuit parameters of propagation delay; noise margin; fan-out; fan-in; and power dissipation for circuits of different logic families, including NMOS, CMOS and BiCMOS; subsystem designs in combinational and sequential logic; Memory Systems; HSPICE circuit simulation is used for digital characteristics evaluation. Mentor Graphics Layout design tools are used for chip design.

ECE 659. Fabrication Principles of Electronic and Optoelectronic Devices. 3 credits, 3 contact hours.
Prerequisite: ECE 657 or equivalent. Overview of all major processing steps in fabrication of integrated circuits such as crystal growth, epitaxy, oxidation, diffusion, ion implantation and etching. Formation of thin film structures along with techniques for defining submicron structures. Emphasizes silicon device technology but also includes processing of compound semiconductors such as gallium arsenide.

ECE 660. Control Systems I. 3 credits, 3 contact hours.
Prerequisites: ECE 601 or equivalent. Introduction to feedback control. Review of state-space analysis. Frequency-domain methods for analysis: Routh-Hurwitz stability algorithms, Root-loci; Nyquist and Bode plots; system ?type.? Controllability and observability. The separation principle and design by pole placement. Linear observers. Optimization of quadratic performance criteria. Elements of random processes. The Kalman filter as an optimum observer. Robustness considerations. Prior undergraduate trainings in Signals and Systems (ECE 333) or Dynamic Systems (ME 305) are necessary.

ECE 661. Control System Components. 3 credits, 3 contact hours.
Prerequisite: ECE 660. The theoretical and practical requirements for analog and digital state-of-the-art control system components are covered. Actuators, amplifiers, sensors, encoders, resolvers and other electromagnetic devices are included. A complete system is designed using current vendor catalog data. Problems affecting the system performance are analyzed using measures of functionality, reliability and cost.

ECE 664. Applied Advanced Control Systems. 3 credits, 3 contact hours.
The course focuses on the practical aspects of modern computer-controlled systems. Topics include 1. fundamentals such as Z-transformation, discrete signals and systems, conversion between continuous systems and discrete systems; 2. control law designs such as state feedback control, optimal control, observers, compensators, PID, input shaping, feedforward control, deadbeat control, and Smith predictor; 3. practical design issues such as actuator saturation, anti-windup, selection of sampling rate, etc.; 4. case studies and 5. a software- and simulation-based term project. Prior undergraduate trainings in Control Systems (ECE 431) is necessary.

ECE 667. Bio-Control Systems. 3 credits, 3 contact hours.
The course provides an introduction to dynamic and control in biological systems, with particular emphasis on engineering aspects of biological oscillators/waves which govern the basic operations of all living organisms and especially higher order life forms. A combination of theoretical and simulation tools will be applied to analyze the qualitative and quantitative properties of selected biological systems. Feedback and control mechanisms in selected biological systems will be introduced. Same as BME 667.

ECE 670. Management Strategies in the Offshore Wind Industry. 3 credits, 3 contact hours.
This course offers students the opportunity to build their knowledge and skills and acquire managerial insights on various stages of the life cycle of a wind farm project including development and planning, wind resource assessment, project design, financing, offshore construction, power generation, monitoring and optimization, and decommissioning. through class discussions, interactions with leaders in the U.S. offshore wind industry. Skills examined and practiced in this course include developing and communicating a vision and leadership brand, systems thinking, team building, and decision making. An important goal of the course is to review an offshore wind business's strengths and weaknesses and formulate strategies to explore renewable energy opportunities as well as to cope with the policy and environmental threats in the United States and beyond. The overall pedagogical objectives are to sharpen the student’s ability to "think strategically" and to diagnose situations from a strategic perspective. Leaders from the U.S. offshore wind industry will be invited to be guest lecturers and teach students the models they use to analyze the internal and external environments of an organization as well as the industry and competitive environments of a company, and examine how they are used in the formulation, implementation, and control of competitive strategy.

ECE 671. Financing Offshore Wind. 3 credits, 3 contact hours.
The course begins with an overview of fundamental financial and economic concepts related to commercial-scale wind energy projects. It will dive into the fundamental aspects of site selection, feasibility studies, and the intricacies of wind resource assessment. The course will explore financial aspects of wind turbines and layout design, addressing considerations for optimal energy production and environmental impact. Students will gain insights into project financing, permitting processes, and regulatory compliance specific to the wind energy sector. Through case studies and real-world examples, students will develop a practical understanding of the entire project life cycle, from initial development to construction, operation, and eventual decommissioning. In addition, the course investigates energy policy, and students will gain insights into the historical and contemporary aspects of the Production Tax Credit (PTC) and Investment Tax Credit (ITC), as well as the evolution of subsidies within the industry.

ECE 673. Random Signal Analysis. 3 credits, 3 contact hours.
Fundamentals of the theory of random variables. Introduction to the theory of random processes. Topics include functions of random variables, sequences of random variables, central limit theorem, properties of random processes, correlation, spectral analysis and linear systems with random inputs.

ECE 681. High-Performance Network Function, Data Center, and Virtualization. 3 credits, 3 contact hours.
The course introduces network algorithms for pragmatic implementations of network functions that target high-performance communications used at different network zones and Internet applications. Examples of such functions are Internet packet address (IP) lookup, packet classification, firewalling, scheduling, service chaining, WAN access, and operations at various levels of the protocol stack. The course also introduces architectures of data-center networks and data-center transport protocols, and the use and impact of virtualization on network functions.

ECE 683. Cloud and IoT Networking and Security. 3 credits, 3 contact hours.
This course will introduce the students to the basic networking concepts that enable the management and security of cloud and IoT networks. This course will start with the study of the fundamentals of computer networking and layering. Then, several techniques and protocols that enable and secure these technologies will be studied such as, specialized and advanced packet capture tips, virtualization / IEEE 802.15 Bluetooth / IEEE 802.15.4 ZigBee / IEEE 802.16e WiMAX / Home RF / ZWave / RFID / Infrared / PBCC / 3G / 4G / 5G, and specialized data traffic reconstruction and viewing techniques.

ECE 684. Advanced Microprocessor Systems. 3 credits, 3 contact hours.
Architecture of advanced microprocessors; CPU architecture, memory management and protection, interrupt and exception facilities, instruction sets, systems aspects including peripheral interfaces, communications ports, and real-time systems. Prior undergraduate trainings in computer architecture, microprocessors, and assembly language programming are necessary.

ECE 689. Computer Arithmetic Algorithms. 3 credits, 3 contact hours.
Data representation, integers, floating point and residue representation. Bounds on arithmetic speed, algorithms for high speed addition, multiplication, and division. Pipelined arithmetic. Hardware implementation and control issues. Prior undergraduate trainings in logic design are necessary.

ECE 690. Computer Systems Architecture. 3 credits, 3 contact hours.
Discusses advanced topics in modern computer systems architecture such as pipelined and superscalar processors, parallel computers (vector, SIMD, MIMD), multithreaded and dataflow architectures, cache and memory hierarchy, and system interconnect architectures. Also discusses relevant system software design issues such as shared memory and message-passing communication models, cache coherence and synchronization mechanisms, latency-hiding techniques, virtual memory management, program partitioning and scheduling. Examples are drawn from real systems. Prior undergraduate trainings in computer architecture are necessary.

ECE 692. Embedded Computing Systems. 3 credits, 3 contact hours.
Introduction of the methodology for the design and implementation of embedded computing systems, and its application to real-world problems. Topics include Embedded System Design Process, UML, ARM Instruct Set Architectures, CPU's Hardware Platforms, Software Design and Analysis, Embedded Operating Systems, Real-Time Scheduling, Hardware Accelerators, Distributed Embedded Systems, and Design Methodology and Quality Assurance. Prior undergraduate trainings in computer architecture are necessary.

ECE 698. Selected Topics in Electrical and Computer Engineering. 3 credits, 3 contact hours.
Special area course given when suitable interest develops. Advance notice of forthcoming topics will be given.

ECE 699. Selected Topics in Electrical and Computer Engineering II. 3 credits, 3 contact hours.
See description for ECE 698 above.

ECE 700B. Master's Project. 3 credits, 3 contact hours.
Approval of the project advisor is required for registration. Experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering. A written report must be submitted to the project advisor. The student cannot register in ECE 700B more than once and the incomplete (I) grade is not allowed. Master's students registering for the first time in Master's Project must take simultaneously the INTD 799 (Responsible Conduct of Research) course.

ECE 701B. Master's Thesis. 3 credits, 3 contact hours.
Approval of the thesis advisor is required for registration. Experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering that can lead to a quality publication. A written thesis must be defended and approved by a committee of at least three faculty members. The student is expected to defend the thesis upon accrual of six thesis credits. Additional registration in ECE 701B, beyond six credits, is required every semester until successful thesis defense (six credits count toward degree requirements and time limits apply). Master's students registering for the first time in Master's Thesis must take simultaneously the INTD 799 (Responsible Conduct of Research) course.

ECE 701C. Master's Thesis. 6 credits, 6 contact hours.
Approval of the thesis advisor is required for registration. Experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering that can lead to a quality publication. A written thesis must be defended and approved by a committee of at least three faculty members. The student must continue registering for three thesis credits (ECE 701B) each semester until successful thesis defense (six credits count toward degree requirements and time limits apply).

ECE 725. Independent Study I. 3 credits, 3 contact hours.
Approvals of the academic advisor and course instructor are required for registration. Students working on their PhD dissertation or MS thesis cannot normally register for this course with their respective dissertation/thesis advisor. This special course covers areas of study in which one or more students may be interested but there is not sufficiently broad interest to warrant a regular course offering. Students may not register for this course more than once.

ECE 726. Independent Study II. 3 credits, 3 contact hours.
Approvals of the academic advisor and course instructor are required for registration. Students working on their PhD dissertation or MS thesis cannot normally register for this course with their respective dissertation/thesis advisor. This special course covers areas of study in which one or more students may be interested but there is not sufficiently broad interest to warrant a regular course offering. Students may not register for this course more than once. Students should only register for ECE 726 if they have taken ECE 725 in a prior semester.

ECE 739. Laser Systems. 3 credits, 3 contact hours.
Prerequisite: ECE 620 or permission of instructor. Optical resonators, laser radiation and oscillation. Laser characteristics: semiconductor lasers, gas and glass lasers; mode-locking, Q-switching. Quantum-well lasers, noise; modulation and detection of laser light, optical systems for communication and computation.

ECE 740. Advanced Digital Signal Processing. 3 credits, 3 contact hours.
Prerequisites: ECE 601, ECE 640 and ECE 673. Topics in stationary discrete time stochastic processes; modeling of discrete time processes, Yule-waker equations, aspects of discrete wiener theory; principle of orthogonality, linear predictors; Levinson-Durbin recursion and algorithm, lattice predictors, method of least squares (RLS) algorithm, systolic array implementation of QRD-Ls.

ECE 742. Communication Systems II. 3 credits, 3 contact hours.
Prerequisites: ECE 642 and ECE 673 or equivalents. Principles of digital communication. Topics include fundamentals of information theory, digital modulation techniques, optimum detector receivers for digitally modulated signals, the bandlimited gaussian channel and intersymbol interference, equalization, spread spectrum, CDMA.

ECE 743. Image Data Hiding, Forensics. 3 credits, 3 contact hours.
Prerequisites: ECE 643 or CS 659 or equivalent As we have entered digital world, information forensics and security have become critically important. With digital images as media, this course covers digital watermarking, reversible data hiding, steganography and steganalysis, forensics and counter-forensics, including image tampering detection, classification of double JPEG/MPEG compressions, camera classification from given images, classification of photographic images from computer graphic images, and so on.

ECE 744. Optimization for Data Engineering. 3 credits, 3 contact hours.
With the emergence of advanced sensing and monitoring technologies, data has become the new oil of our digital economy. In all the engineering fields, ranging from power systems and transportation systems to online shopping, web servers, sensors and cameras are continuously collecting huge amounts of data, but this data will not have any meaning without proper processing, analysis, and learning. Optimization techniques provide the core foundation for the processing of the data and learning from it. This course covers the basic analytical and algorithmic optimization tools that lay the foundation for the data analytics and deep learning systems. Specific topics include single-objective convex optimization (duality, optimality conditions, algorithms), gradients-based methods, and the fundamentals of multi-objective optimization and game theory. The theoretical foundation and the fundamental algorithms are applied to real-world scenarios that utilize supervised learning models, including nonlinear regression, logistic regression, support vector machines, and deep neural networks.

ECE 747. Signal Decomposition Techniques: Transforms, Sub-bands, and Wavelets. 3 credits, 3 contact hours.
Prerequisites: ECE 640 and ECE 673. Multiresolution signal decomposition techniques, transforms, sub-bands, and wavelets. Time-frequency localization properties of multiresolution algorithms. Evaluation and critique of proposed decomposition strategies from compression and performance standpoints. Applications to speech and video compression, and localized feature extraction. These are basic signal processing tools used in diverse applications such as speech and image processing and storage, seismology, machine vision.

ECE 754. Statistical Machine Learning for Engineers and Data Scientists. 3 credits, 3 contact hours.
Prerequisites: Good knowledge of statistics and probability, as covered in ECE 673 or similar courses, and linear algebra; or permission of instructor. With the explosion of “Big Data” problems, statistical learning has become a very hot field in many scientific areas as well as in marketing, finance, and business. Statistical learning refers to a vast set of tools for understanding data. Specifically, supervised statistical learning involves building a statistical model to predict or estimate an output or pattern based on one or more inputs. For unsupervised learning there are inputs, but no supervising output, and here the goal is to learn relationships and structure from the data. This course provides a systematic introduction to statistical machine learning and pattern recognition using fundamental performance criteria as guiding principles and studies how these principles affect real-world performance. Topics covered include practical techniques as linear and kernel models for classification and regression, unsupervised probabilistic modeling, probabilistic graphical models, and approximate inference, but also theoretical underpinnings as VC dimension and sample complexity.

ECE 755. Advanced Topics in Digital Communications. 3 credits, 3 contact hours.
Prerequisites: ECE 642 and ECE 673 or equivalent. Advanced topics in digital communication systems in the presence of intersymbol interference, noise, and fading: modulation and demodulation in the presence of gaussian noise, efficient signaling with coded modulation, trellis decoding, Viterbi algorithm, digital transmission with intersymbol interference, and digital signaling over imperfect channels.

ECE 756. Advanced Topics in Semiconductor Devices. 3 credits, 3 contact hours.
Prerequisite: ECE 657 or permission of instructor. Builds on ECE 657. Covers photonic devices particularly semiconductor laser and photodetectors for optical systems; microwave and other high speed devices; scaled advanced MOS, FET, and bipolar transistors.

ECE 758. VLSI Design II. 3 credits, 3 contact hours.
Prerequisite: ECE 658 (with ECE 657 suggested). Use of CMOS, biCMOS and bipolar semiconductor technology for VLSI design. Digital techniques are emphasized with minor coverage of analog design. Application areas for full custom, gate arrays, standard cell, and compiled designs are compared. Mentor VLSI design tools running on the HP and Sun workstations are used in the course projects for each enrollee. The course attempts to provide a design environment for projects that is similar to that encountered by VLSI designers in industry.

ECE 760. Control Systems II. 3 credits, 3 contact hours.
Prerequisites: ECE 601 and ECE 660. Properties of nonlinear systems and basic concepts of stability including small-signal linearization. State plane methods are introduced, with emphasis on controller design for systems that can be represented by second-order approximations. Concepts of equivalent gain, describing function, and dual-input describing function as applied to a large class of nonlinear systems. Representation of linear sampled-data systems in discrete state variable form, stability and performance of discrete-event systems. Full-state feedback, pole placement and observer design. Linear quadratic control and Kalman filtering.

ECE 776. Information Theory. 3 credits, 3 contact hours.
Prerequisites: ECE 642 and ECE 673 or equivalents. Classical theory of information developed from Shannon's theory. Information measure, Markov sources and extensions, the adjoint source, uniquely decodable and instantaneous codes and their construction, Shannon's first and second theorems, mutual information, and performance bounds on block and convolutional codes.

ECE 777. Statistical Decision Theory in Communications. 3 credits, 3 contact hours.
Prerequisite: ECE 642 or equivalent. Relation between detection theory and statistical hypothesis testing problem. Use of Bayes decision criteria, Neyman-Pearson, and mini-max tests; receiver operating characteristics. Representation of signals in signal space, probability of error calculations. Estimation of random and non-random signal parameters, Cramer-Rao Inequality. The general Gaussian problem and the use of covariance matrices.

ECE 783. Computer Communication Networks. 3 credits, 3 contact hours.
Prerequisites: ECE 673 and ECE 683. Data link control and communication channels. Delay models in data networks. Queueing analysis techniques are taught in detail. Multi-access communication techniques. Routing in computer communication networks.

ECE 788. Selected Topics in Electrical and Computer Engineering. 3 credits, 3 contact hours.
Special-area course given when suitable interest develops. Advance notice of forthcoming topics will be given.

ECE 789. Selected Topics in Electrical and Computer Engineering II. 3 credits, 3 contact hours.
See description for ECE 788.

ECE 790A. Doctrl Dissrtn & Research. 1 credit, 1 contact hour.
Co-requisite: ECE 791. Approval of the dissertation advisor is required for registration. Experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering. For PhD students who have successfully defended their dissertation proposal. The student must register in ECE 790A every semester until successful dissertation defense. A written dissertation must be defended and approved by a committee of at least five members. Students enrolled in the PhD program before 2015 Fall must accumulate a minimum number of credits in Doctoral Dissertation Research and Pre-Doctoral Research (see graduate catalog for program-specific details; the same requirement may apply to joint PhD programs with other universities).

ECE 791. Graduate Seminar. 0 credits, 0.5 contact hours.
All master's and doctoral students must register for two semesters and six semesters of ECE 791 Graduate Seminar, respectively. To receive a satisfactory grade, students must attend at least five seminars during the semester, as approved by the seminar supervisor.

ECE 792B. Pre-Doctoral Research. 3 credits, 3 contact hours.
Co-requisite: ECE 791. Approval of the dissertation advisor is required for registration. Preliminary experimental and/or theoretical investigation of a relevant topic in electrical or computer engineering. For students who have passed the qualifying examination but have not defended the dissertation proposal. Permission is needed of the academic advisor as well for students who have completed the required coursework but have not passed the qualifying examination.