Department of Electrical and Computer Engineering

231 Kaufman Hall
757-683-3741

http://www.odu.edu/ece/ (http://eng.odu.edu/ece/)

```
Oscar González, Chair
Yuzhong Shen, Associate Chair
Chung-Hao Chen, Graduate Program Director, Electrical &
 Computer Engineering
Michel Audette, Graduate Program Director, Biomedical
 Engineering
Hong Yang, Graduate Program Director, Modeling and Simulation
Chung-Hao Chen, Graduate Program Director, Doctor of
 Engineering, Cybersecurity
```

Overview

The Department of Electrical and Computer Engineering strives to provide the highest quality engineering education at the undergraduate and graduate levels, to engage in scholarly research at the forefront of electrical, computer, and biomedical engineering, and to serve the professions of electrical, computer, modeling and simulation, and biomedical engineering. The department has strong graduate and research programs providing a high quality and broad-based education that prepares graduates for successful professional careers and a lifetime of learning. The Electrical & Computer Engineering Department also offers a Doctor of Engineering Degree in Cybersecurity. This program is available on-campus and online.

Electrical and Computer Engineering graduate studies encompass six broad areas:

1. systems
2. signal and image processing
3. physical electronics
4. computer engineering
5. cybersecurity engineering
6. modeling and simulation engineering

List of Degrees and Certificates

The department offers the following Electrical and Computer Engineering graduate degrees:

- Master of Science, Engineering - Electrical and Computer Engineering (Traditional and Online Formats)
- Doctor of Philosophy, Engineering - Electrical and Computer Engineering
- Doctor of Engineering, Electrical and Computer Engineering
- Doctor of Engineering, Cybersecurity

and

- Master of Science, Engineering - Modeling and Simulation
- Doctor of Philosophy, Engineering - Modeling and Simulation
- Doctor of Engineering - Modeling and Simulation
- Graduate Certificate in Modeling and Simulation Engineering

The department also administers the following Biomedical Engineering graduate degrees and a certificate.

- Master of Engineering - Biomedical Engineering
- Master of Science, Engineering - Biomedical Engineering
- Doctor of Philosophy, Engineering - Biomedical Engineering
- Advanced Engineering Certificate - Biomedical Engineering

Programs

Doctor of Engineering Programs

- Engineering with a Concentration in Cybersecurity (DEng) (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/engineering-cybersecurity-deng/)
- Engineering with a Concentration in Electrical and Computer Engineering (DEng) (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/engineering-electrical-computer-deng/)
- Engineering with a Concentration in Modeling and Simulation (DEng) (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/engineering-modeling-simulation-deng/)

Doctor of Philosophy Programs

- Engineering with a Concentration in Biomedical Engineering (PhD) (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/engineering-biomedical-phd/)
- Engineering with a Concentration in Electrical and Computer Engineering (PhD) (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/engineering-electrical-computer-phd/)
- Engineering with a Concentration in Modeling and Simulation Engineering (PhD) (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/engineering-modeling-simulation-phd/)

Master of Engineering Program

- Engineering with a Concentration in Biomedical Engineering (ME) (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/engineering-biomedical-me/)

Master of Science Programs

- Engineering with a Concentration in Biomedical Engineering (MS) (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/engineering-biomedical-ms/)
- Engineering with a Concentration in Electrical and Computer Engineering (MS) (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/engineering-electrical-computer-ms/)
- Engineering with a Concentration in Modeling and Simulation (MS) (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/engineering-modeling-simulation-ms/)

Certificate Program

- Modeling and Simulation - Engineering Certificate (http://catalog.odu.edu/graduate/engineering-technology/electrical-computer-engineering/modeling-simulation-engineering-certificate/)

Courses

Biomedical Engineering (BME)

BME 503 Introduction to Mathematical Modeling in Physiology (3 Credit Hours)
This course introduces model development and model formulation with differential equations in physiology. Students will learn how to use Matlab to solve differential equations and visualize their results. The physiological focus will be on cellular physiology, particularly ion channel dynamics and homeostasis.
Prerequisites: BIOL 240 or BIOL 250 and MATH 200 or MATH 205 or MATH 211

BME 504 Introduction to Biomaterials (3 Credit Hours)
This course will introduce the properties of biomedical materials used as implants, prostheses, orthosis, and tissue-engineered materials as medical devices in contact with tissues and organs. Biocompatibility, immunological responses, wound healing, clotting cascade, surface compatibility and characterization of materials used for implantable medical devices will be introduced. Other topics such as ethical considerations and medical device regulatory mechanisms will be presented.
Prerequisites: BIOL 240 or BIOL 250 and MATH 200 or MATH 205 or MATH 211

BME 505 Biomechanics (3 Credit Hours)
The purpose of this course is to achieve a broad overview of biomechanics, focused on the musculoskeletal system. Students will explore multiscale mechanics, including whole-body movement and mechanical properties of the structures in the musculoskeletal system. Additionally, students will survey the experimental methods and computational modeling techniques used in biomechanics research.
Prerequisites: BIOL 240 or BIOL 250, and MATH 212

BME 509 Introduction to Regenerative Medicine (3 Credit Hours)
This course will introduce fundamental knowledge in regenerative medicine including therapeutic applications of biomaterials, tissue and stem cell engineering, gene therapy and bioelectrics, with emphasis on structure-function relationships of biologic systems. In addition to lecture, students will have opportunities for group discussions and presentations on milestone work related to tissue regeneration. Students will leave with a thorough understanding of true mammalian regeneration, wound healing/repair processes, and medical device milestones as related to human tissue regeneration and repair.
Prerequisites: BIOL 240 or BIOL 250 and MATH 200 or MATH 205 or MATH 211

BME 554 Introduction to Bioelectrics (3 Credit Hours)
This course covers the electrical properties of cells and tissues as well as the use of electrical and magnetic signals and stimuli in the diagnosis and treatment of disease. Typical topics to be covered include basic cell physiology, endogenous electric fields in the body, electrocardiography, cardiac pacing defibrillation, electrotherapy, electroporation, electrotherapy in wound healing. In addition ultra-short electrical pulses for intracellular manipulation and the application of plasmas to biological systems will be covered.

BME 562 Introduction to Medical Image Analysis (3 Credit Hours)
Introduction to basic concepts in medical image analysis. Medical image registration, segmentation, feature extraction, and classification are discussed. Basic psychophysics, fundamental ROC analysis and FROC methodologies are covered. Cross-listed with ECE 562/MSIM 562.

BME 564 Biomedical Applications of Low Temperature Plasmas (3 Credit Hours)
This course is cross listed with ECE and Biology. It is designed to be taken by senior undergraduate students and first year graduate students. The course contents are multidisciplinary, combining materials from engineering and the biological sciences. The course covers an introduction to the fundamentals of non-equilibrium plasmas, low temperature plasma sources, and cell biology. This is followed by a detailed discussion of the interaction of low temperature plasma with biological cells, both prokaryotes and eukaryotes. Potential applications in medicine such as wound healing, blood coagulation, sterilization, and the killing of various types of cancer cells will be covered.
Prerequisites: Senior standing

BME 612 Digital Signal Processing I (3 Credit Hours)
This course will present the fundamentals of digital signal processing. Topics will include frequency domain analysis of discrete-time linear systems, sampling and reconstruction of signals, the Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT), and digital filter design and implementations. Practical applications and examples will be discussed. Problem solving using MATLAB is required. Cross-listed with ECE 612.
Prerequisites: ECE 381 or equivalent

BME 695 Topics in Biomedical Engineering (3 Credit Hours)
This course will be offered as needed, depending upon the need to introduce special subjects to target specific areas of master's-level specializations in biomedical engineering.

BME 698 Master's Project (1-3 Credit Hours)
Individual project directed by the student's professor in major area of study.

BME 699 Master's Thesis (1-9 Credit Hours)
Directed research for the master's thesis.
Prerequisites: departmental approval

BME 720 Modern Biomedical Instrumentation (3 Credit Hours)
This course covers the design of modern biomedical instruments including select diagnostic, assistive, therapeutic, prosthetic, imaging, and virtual devices and systems. Techniques for mechanical, electrical, and chemical sensor and transducer design; stimulation and measurement; data acquisition; digital signal processing; and data visualization will be examined.

BME 721 Mathematical Modeling in Physiology (3 Credit Hours)
This course on mathematical modeling in human physiology emphasizes the development of mathematical models, their implementation, and the interpretation of simulation data. The course focuses on cellular physiology, including membrane channels, excitability, and calcium dynamics; it also covers intercellular communication and spatially distributed systems.

BME 724 Neural Engineering (3 Credit Hours)
This course presents engineering techniques for the restoration and augmentation of human function via direct interactions between the nervous system and artificial devices, with particular emphasis on brain-computer interfaces. Novel interfaces, hardware and computational issues, and practical and ethical considerations will also be covered.

BME 726 Biomaterials (3 Credit Hours)
This course cover fundamental principles and properties of biomedical materials used as implants, prostheses, orthosis, and tissue-engineered materials as medical devices in contact with tissues and organs. Advanced concepts of biocompatibility and material characterization will be discussed. Physiological response factors associated with materials and implanted devices used in the human body will be presented, including immunological responses, wound healing, clotting cascade and surface compatibility. Other topics such as ethical considerations and medical device regulatory mechanisms will be discussed.

BME 730 Predoctoral Fellowship Grant Writing (1 Credit Hour)
This course provides students important tools and experience in the vital grantsmanship area, which is needed to succeed in the competitive academic landscape. Students will be exposed to information regarding major predoctoral fellowships including NIH, NSF, DoD, and AHA, culminating in a grant proposal submission to the appropriate institution.

BME 740 Regenerative Medicine (3 Credit Hours)
This course covers a range of active research topics in regenerative medicine, including therapeutic applications of biomaterials, tissue and stem cell engineering, gene therapy and bioelectrics, with emphasis on structure-function relationships of biological systems. Upon completion of the course students should leave with a thorough understanding of biological systems structure-function relationships and associated biomimetic therapeutic approaches in regenerative medicine.
Prerequisites: BIOL 240 or BIOL 250 and MATH 200 or MATH 205 or MATH 211

BME 741 Principles of Visualization (3 Credit Hours)
Well-designed graphical media capitalizes on human facilities for processing visual information and thereby improves comprehension, memory, inference, and decision making. This course teaches techniques and algorithms for creating effective visualizations based on principles and techniques from graphic design, visual art, perceptual psychology and cognitive science. Both users and developers of visualization tools and systems will benefit from this course.

BME 747 Responsible Conduct of Research (2 Credit Hours)
The course will introduce students to the responsible conduct of science and scientific research.

BME 751 Computational and Statistical Methods in Biomedical Engineering (3 Credit Hours)
This course covers the theoretical foundation and application of commonly used techniques in biomedical engineering. Topics include linear algebra, partial differential equations, regression analysis, applied probabilities, multivariate distributions, Bayesian statistics, hypothesis tests, multiple comparisons, ANOVA, solution of non-linear equations, numerical methods and optimization. Programming software will be used to perform simulations and analyze biomedical data.
Prerequisites: Graduate status

BME 754 Advanced Bioelectrics (3 Credit Hours)
Bioelectrics is a new field encompassing both the science and technology of applying electrical stimuli to biological systems. This course covers the pulsed power technology that is required to generate electrical stimuli as well as the biological responses they evoke in cells and tissues. Particular emphasis is placed on the medical applications of bioelectrics, including tumor ablation, gene electrotransfer, wound healing, decontamination with cold plasma, and treatment of cardiac arrhythmias.
Prerequisites: ECE 454 or ECE 554 or BIOE 454 or BIOE 554

BME 755 Biomembranes and Ion Channels (3 Credit Hours)
This course will give an overview of the structure and dynamics of biomembranes, the ion channels that are embedded in them, and the electrical properties of biomembranes. Topics include molecular dynamics modeling of biomembranes, membrane damage and repair, ion channel dynamics and their experimental assessment using patch clamping, and excitability in neurons and cardiomyocytes.
Prerequisites: ECE 454 or ECE 554 or BIOL 523

BME 762 Applied Medical Image Analysis (3 Credit Hours)
Course explores hands-on exposure to state-of-the-art algorithms in medical image analysis, which builds on open-source software (Insight Segmentation and Registration Toolkit - ITK), as well as the principles of medical image acquisition in the modalities of clinical interest. Medical imaging modalities - X-rays, CT, and MRI/ITK image pipeline; image enhancement, feature detection; segmentation - basic techniques, feature-based classification and clustering, graph cuts, active contour and surface models; surface and volume meshing; registration - transformations, similarity criteria; shape and appearance models are all explored and discussed in this course.
Prerequisites: Knowledge of C++ and object-oriented programming

BME 783 Digital Image Processing (3 Credit Hours)
Principles and techniques of two-dimensional processing of images. Concepts of scale and spatial frequency. Image filtering in spatial and transform domains. Applications include image enhancement and restoration, image compressing, biomedical imaging for diagnosis of disease, and image segmentation for computer vision.
Prerequisites: ECE 782 or ECE 882

BME 792 Biomechanics (3 Credit Hours)
The purpose of this course is to achieve a broad overview of biomechanics, focused on the musculoskeletal system. Students will explore multiscale mechanics, including whole-body movement and mechanical properties of the structures in the musculoskeletal system. Additionally, students will survey the experimental methods and computational modeling techniques used in biomechanics research.
Prerequisites: MATH 212 or equivalent

BME 794 Cellular Biomechanics (3 Credit Hours)
A broad introduction to the field of cellular biomechanics. Topics include overview of cell architecture, cytoskeleton, adhesion and molecular motors, biomolecular/biopolymer dynamics and mechanics, techniques to measure cell mechanical properties, techniques to mechanically stimulate cells, models of cell mechanical behavior, mechanobiology and mechanotransduction. Will include discussion of classic and current research articles. Course content will aim to cater to students with diverse backgrounds – students with biological science background will be exposed to physical science concepts and analysis; students with engineering/physical science background will be exposed to biological phenomena and concepts.
Pre- or corequisite: MATH 212

BME 795 Special Topics in Biomedical Engineering (1-3 Credit Hours)
Special courses covering selected graduate-level topics in biomedical engineering.

BME 797 Independent Study (1-3 Credit Hours)
This course allows students to develop specialized expertise by independent study (supervised by a faculty member).
Prerequisites: departmental approval

BME 820 Modern Biomedical Instrumentation (3 Credit Hours)
This course covers the design of modern biomedical instruments including select diagnostic, assistive, therapeutic, prosthetic, imaging, and virtual devices and systems. Techniques for mechanical, electrical, and chemical sensor and transducer design; stimulation and measurement; data acquisition; digital signal processing; and data visualization will be examined.

BME 821 Mathematical Modeling in Physiology (3 Credit Hours)
This course on mathematical modeling in human physiology emphasizes the development of mathematical models, their implementation, and the interpretation of simulation data. The course focuses on cellular physiology, including membrane channels, excitability, and calcium dynamics; it also covers intercellular communication and spatially distributed systems.

BME 824 Neural Engineering (3 Credit Hours)
This course presents engineering techniques for the restoration and augmentation of human function via direct interactions between the nervous system and artificial devices, with particular emphasis on brain-computer interfaces. Novel interfaces, hardware and computational issues, and practical and ethical considerations will also be covered.

BME 826 Biomaterials (3 Credit Hours)
This course cover fundamental principles and properties of biomedical materials used as implants, prostheses, orthosis, and tissue-engineered materials as medical devices in contact with tissues and organs. Advanced concepts of biocompatibility and material characterization will be discussed. Physiological response factors associated with materials and implanted devices used in the human body will be presented, including immunological responses, wound healing, clotting cascade and surface compatibility. Other topics such as ethical considerations and medical device regulatory mechanisms will be discussed.

BME 830 Predoctoral Fellowship Grant Writing (1 Credit Hour)
This course provides students important tools and experience in the vital grantsmanship area, which is needed to succeed in the competitive academic landscape. Students will be exposed to information regarding major predoctoral fellowships including NIH, NSF, DoD, and AHA, culminating in a grant proposal submission to the appropriate institution.

BME 840 Regenerative Medicine (3 Credit Hours)
This course covers a range of active research topics in regenerative medicine, including therapeutic applications of biomaterials, tissue and stem cell engineering, gene therapy and bioelectrics, with emphasis on structure-function relationships of biological systems. Upon completion of the course students should leave with a thorough understanding of biological systems structure-function relationships and associated biomimetic therapeutic approaches in regenerative medicine.
Prerequisites: BIOL 240 or BIOL 250 and MATH 200 or MATH 205 or MATH 211

BME 841 Principles of Visualization (3 Credit Hours)
Well-designed graphical media capitalizes on human facilities for processing visual information and thereby improves comprehension, memory, inference, and decision making. This course teaches techniques and algorithms for creating effective visualizations based on principles and techniques from graphic design, visual art, perceptual psychology and cognitive science. Both users and developers of visualization tools and systems will benefit from this course.

BME 847 Responsible Conduct of Research (2 Credit Hours)
The course will introduce students to the responsible conduct of science and scientific research.

BME 851 Computational and Statistical Methods in Biomedical Engineering (3 Credit Hours)
This course covers the theoretical foundation and application of commonly used techniques in biomedical engineering. Topics include linear algebra, partial differential equations, regression analysis, applied probabilities, multivariate distributions, Bayesian statistics, hypothesis tests, multiple comparisons, ANOVA, solution of non-linear equations, numerical methods and optimization. Programming software will be used to perform simulations and analyze biomedical data.
Prerequisites: Graduate status

BME 854 Advanced Bioelectrics (3 Credit Hours)
Bioelectrics is a new field encompassing both the science and technology of applying electrical stimuli to biological systems. This course covers the pulsed power technology that is required to generate electrical stimuli as well as the biological responses they evoke in cells and tissues. Particular emphasis is placed on the medical applications of bioelectrics, including tumor ablation, gene electrotransfer, wound healing, decontamination with cold plasma, and treatment of cardiac arrhythmias.
Prerequisites: ECE 454 or ECE 554 or BIOE 454 or BIOE 554

BME 855 Biomembranes and Ion Channels (3 Credit Hours)
This course will give an overview of the structure and dynamics of biomembranes, the ion channels that are embedded in them, and the electrical properties of biomembranes. Topics include molecular dynamics modeling of biomembranes, membrane damage and repair, ion channel dynamics and their experimental assessment using patch clamping, and excitability in neurons and cardiomyocytes.
Prerequisites: ECE 454 or ECE 554 or BIOL 523

BME 862 Applied Medical Image Analysis (3 Credit Hours)
Course explores hands-on exposure to state-of-the-art algorithms in medical image analysis, which builds on open-source software (Insight Segmentation and Registration Toolkit - ITK), as well as the principles of medical image acquisition in the modalities of clinical interest. Medical imaging modalities - X-rays, CT, and MRI/ITK image pipeline; image enhancement, feature detection; segmentation - basic techniques, feature-based classification and clustering, graph cuts, active contour and surface models; surface and volume meshing; registration - transformations, similarity criteria; shape and appearance models are all explored and discussed in this course.
Prerequisites: Knowledge of C++ and object-oriented programming

BME 883 Digital Image Processing (3 Credit Hours)
Principles and techniques of two-dimensional processing of images. Concepts of scale and spatial frequency. Image filtering in spatial and transform domains. Applications include image enhancement and restoration, image compressing, biomedical imaging for diagnosis of disease, and image segmentation for computer vision.
Prerequisites: ECE 783 and ECE 883

BME 892 Biomechanics (3 Credit Hours)
The purpose of this course is to achieve a broad overview of biomechanics, focused on the musculoskeletal system. Students will explore multiscale mechanics, including whole-body movement and mechanical properties of the structures in the musculoskeletal system. Additionally, students will survey the experimental methods and computational modeling techniques used in biomechanics research.
Prerequisites: MATH 212 or equivalent

BME 894 Cellular Biomechanics (3 Credit Hours)
A broad introduction to the field of cellular biomechanics. Topics include overview of cell architecture, cytoskeleton, adhesion and molecular motors, biomolecular/biopolymer dynamics and mechanics, techniques to measure cell mechanical properties, techniques to mechanically stimulate cells, models of cell mechanical behavior, mechanobiology and mechanotransduction. Will include discussion of classic and current research articles. Course content will aim to cater to students with diverse backgrounds – students with biological science background will be exposed to physical science concepts and analysis; students with engineering/physical science background will be exposed to biological phenomena and concepts.
Pre- or corequisite: MATH 212

BME 895 Special Topics in Biomedical Engineering (1-3 Credit Hours)
Special courses covering selected graduate-level topics in biomedical engineering.

BME 897 Independent Study (1-3 Credit Hours)
This course allows students to develop specialized expertise by independent study (supervised by a faculty member).
Prerequisites: departmental approval

BME 899 PHD Dissertation Research (1-9 Credit Hours)
Directed research for the doctoral dissertation.

BME 999 Doctoral Graduate Credit (1 Credit Hour)
This course is a pass/fail course doctoral students may take to maintain active status after successfully passing the candidacy examination. All doctoral students are required to be registered for at least one graduate credit hour every semester until their graduation.

Electrical and Computer Engineering (ECE)

ECE 503 Power Electronics (3 Credit Hours)
Power electronics provides the needed interface between an electrical source and an electrical load and facilitates the transfer of power from a source to a load by converting voltages and currents from one form to another. Topics include: alternating voltage rectification, Pulse Width Modulation (PWM), DC converters (Buck, Boost, Buck-Boost, Cuk and SEPIC converters), negative feedback control in power electronics, isolated switching mode power supply, flyback and forward power supply, solid state power switches, AC inverter. (Offered spring)
Prerequisites: ECE 303, ECE 313 and a grade of C or better in ECE 202 and ECE 287

ECE 504 Electric Drives (3 Credit Hours)
Electric drives efficiently control the torque, speed and position of electric motors. This course has a multi-disciplinary nature and includes fields such as electric machine theory, power electronics, and control theory. Topics include: switch-mode power electronics, magnetic circuit, DC motor, AC motor, Brushless DC motor, induction motor, speed control of induction motor, vector control of induction motor, stepper-motor. (offered fall)
Prerequisites: ECE 303 and a grade of C or better in ECE 202 and ECE 287

ECE 505 Power System Design & Analysis (3 Credit Hours)
This course covers basic power circuit analysis and introductory power system engineering and focuses on the transmission line design, power flow study, short circuit protection, and power distribution in electric power systems, followed by a survey of several applications and case studies. (offered fall)
Prerequisites: ECE 303 or equivalent knowledge in electric machines and circuits

ECE 506 Computer Graphics and Visualization (3 Credit Hours)
The course provides a practical treatment of computer graphics and visualization with emphasis on modeling and simulation applications. It covers digital image and signal processing basics such as sampling and discrete Fourier transform, computer graphics fundamentals, visualization principles, and software architecture for visualization in modeling and simulation. Written communication and information literacy skills are stressed in this course. (Cross listed with MSIM 541.) (Offered fall)
Prerequisites: ECE 348 or CS 361 or MSIM 331 or MSIM 603

ECE 507 Introduction to Game Development (3 Credit Hours)
An introductory course focused on game development theory and modern practices with emphasis on educational game development. Topics include game architecture, computer graphics theory, user interaction, audio, high level shading language, animation, physics, and artificial intelligence. The developed games can run on a variety of computer, mobile, and gaming platforms. (Cross listed with MSIM 508.) (Offered spring)
Prerequisites: CS 361 or MSIM 331 or ECE 348

ECE 508 Fundamentals of Electric Vehicles (3 Credit Hours)
This course covers the fundamentals of electric vehicles and focuses on the components, power control, energy management, power train dynamics and other related topics in purely electric and hybrid electric vehicle systems, including a survey of several applications and case studies. (Offered spring)
Prerequisites: ECE 303 and a grade of C or better in ECE 202 and ECE 287

ECE 509 Introduction to Distributed Simulation (3 Credit Hours)
An introduction to distributed simulation. Topics include motivation for using distributed simulation, distributed simulation architectures, time management issues, and distributed simulation approaches. Current standards for distributed simulation are presented.
Prerequisites: MSIM 331 or ECE 348

ECE 510 Model Engineering (3 Credit Hours)
The goal of this course is to develop understanding of the various modeling paradigms appropriate for capturing system behavior and conducting digital computer simulation of many types of systems. The techniques and concepts discussed typically include UML, concept graphs, Bayesian nets, Markov models, Petri nets, system dynamics, Bond graphs, etc. Students will report on a particular technique and team to implement a chosen system model. (Cross-listed with MSIM 510.) (Offered spring)
Prerequisites: MSIM 205 or equivalent
Pre- or corequisite: MSIM 320 or equivalent

ECE 516 Cyber Defense Fundamentals (3 Credit Hours)
This course focuses on cybersecurity theory, information protection and assurance, and computer systems and networks security. The objectives are to understand the basic security models and concepts, learn fundamental knowledge and tools for building, analyzing, and attacking modern security systems, and gain hands-on experience in cryptographic algorithms, security fundamental principles, and Internet security protocol and standards. (Offered fall)
Prerequisites: Permission of the instructor
Pre- or corequisite: ECE 355

ECE 519 Cyber Physical System Security (3 Credit Hours)
Cyber Physical Systems (CPS) integrate computing, networking, and physical processes. The objectives of this course are to learn the basic concepts, technologies and applications of CPS, understand the fundamental CPS security challenges and national security impact, and gain hands-on experience in CPS infrastructures, critical vulnerabilities, and practical countermeasures. (Offered spring)
Prerequisites: ECE 355 or permission of the instructor

ECE 541 Advanced Digital Design and Field Programmable Gate Arrays (3 Credit Hours)
Course will present FPGA technologies and methods using CAD design tools for implementation of digital systems using FPGAs. Topics include advanced methods of digital circuit design including specification, synthesis, implementation and prototyping; managing multiple clock domains, static timing analysis, timing closure, system reset design, simulation, and optimization; troubleshooting using embedded logic analyzers and integrated development environments (IDEs). Practical system design examples include general purpose data processing, system on a chip (SOC) prototyping, hardware accelerators, and an introduction to domain specific architectures. (Offered spring)
Prerequisites: ECE 341

ECE 543 Computer Architecture (3 Credit Hours)
An introduction to computer architectures. Analysis and design of computer subsystems including central processing units, memories and input/output subsystems. Important concepts include datapaths, computer arithmetic, instruction cycles, pipelining, virtual and cache memories, direct memory access and controller design. (offered fall)
Prerequisites: ECE 341 and ECE 346

ECE 545 Introduction to Computer Vision (3 Credit Hours)
Overview of digital image processing including visual perception, image formation, spatial transformations, image enhancement, color image representation and processing, edge detection, image segmentation, and data processing method for computer vision applications. Hand-on projects will be introduced to better understand computer vision applications. (Offered fall)
Prerequisites: A grade of C or better in ENGN 150 or CS 150
Pre- or corequisite: ECE 350

ECE 550 Introduction to Machine Learning for Data Analytics Engineering (3 Credit Hours)
Machine Learning provides a practical treatment of design, analysis and implementation of algorithms, which learn from examples. Topics include multiple machine learning models: linear regression, logistic regression, neural networks, support vector machines, deep learning, Bayesian learning and unsupervised learning. Students are expected to use popular machine learning tools and algorithms to solve real data engineering problems. (Offered spring)
Prerequisites: A grade of C or better in ENGN 150 or CS 150
Pre- or corequisite: ECE 350

ECE 551 Communication Systems (3 Credit Hours)
Fundamentals of communication systems engineering. Modulation methods including continuous waveform modulation (amplitude, angle). Design and analysis of modulation systems and the performance in the presence of noise. Communication simulation exercises through computer experiments. (Offered spring)
Prerequisites: ECE 304 and ECE 302

ECE 552 Introduction to Wireless Communication Networks (3 Credit Hours)
Introduction to current wireless network technologies and standards. The radio frequency spectrum and radio wave propagation models (pathloss, fading, and multipath). The radio link and link budgets. Modulation, diversity, and multiple access techniques. Wireless network planning and operation. Current and emerging wireless technologies (satellite systems, vehicular/sensor networks). (Offered fall)
Prerequisites: ECE 304 and ECE 302

ECE 553 Analysis for Modeling and Simulation (3 Credit Hours)
An introduction to analysis techniques appropriate to the conduct of modeling and simulation studies. Topics include input modeling, random number generation, output analysis, variance reduction techniques, and experimental design. In addition, techniques for verification & validation are introduced. Course concepts are applied to real systems and data.
Prerequisites: MSIM 205 or ECE 306 and ECE 304

ECE 554 Introduction to Bioelectrics (3 Credit Hours)
Covers the electrical properties of cells and tissues as well as the use of electrical and magnetic signals and stimuli in the diagnosis and treatment of disease. Typical topics to be covered include basic cell physiology, endogenous electric fields in the body, electrocardiography, cardiac pacing, defibrillation, electrotherapy, electroporation, electrotherapy in wound healing. In addition, ultrashort electrical pulses for intracellular manipulation and the application of plasmas to biological systems will be covered. (Offered fall)
Prerequisites: PHYS 111N or higher; MATH 200 or higher

ECE 555 Network Engineering and Design (3 Credit Hours)
Emphasis is on gaining an understanding of networking design principles that entails all aspects of the network development life cycle. Topics include campus LAN models and design, VLANs, internetworking principles and design, WAN design, design of hybrid IP networks, differentiated vs. integrated services, traffic flow measurement and management. (offered spring)
Prerequisites: ECE 355 or permission of the instructor

ECE 558 Instrumentation (3 Credit Hours)
Computer interfacing using a graphical programming language with applications involving digital-to-analog conversion (DAC), analog-to-digital conversion (ADC), digital input output (DIO), Virtual Instrument System Architecture (VISA) and universal Service Bus (USB). Analysis of sampled data involving use of probability density function, mean and standard derivations, correlations, and the power spectrum. (offered spring, summer)
Prerequisites: ECE 302 or permission of the instructor

ECE 561 Automatic Control Systems (3 Credit Hours)
Analysis and design of control systems as found in automobiles and aircraft, autonomous vehicles, robots, and many other engineering systems. Time and frequency domain techniques such as root locus, Bode, Nyquist and state space techniques are utilized together with computer-aided analysis and design. (Offered fall)
Prerequisites: ECE 302

ECE 562 Introduction to Medical Image Analysis (MIA) (3 Credit Hours)
Introduction to basic concepts in medical image analysis. Medical image registration, segmentation, feature extraction, and classification are discussed. Basic psychophysics, fundamental ROC analysis and FROC methodologies are covered. (Offered every other spring)
Prerequisites: a grade of C or better in MATH 212

ECE 563 Design and Modeling of Autonomous Robotic Systems (3 Credit Hours)
This course focuses on autonomous robotics systems with emphasis on using modeling and simulation (M&S) for system level design and testing. Fundamental concepts associated with autonomous robotic systems are discussed. Course topics include: robotic control, architectures, and sensors as well as more advanced concepts such as error propagation, localization, mapping and autonomy. Design strategies that leverage M&S to accelerate the development and testing of sophisticated autonomous robotic algorithms for individual or teams of robots are covered.
Prerequisites: CS 150 or ENGN 150

ECE 564 Biomedical Applications of Low Temperature Plasmas (3 Credit Hours)
This course is cross listed between ECE, BME and BIOL. It is designed to be taken by senior undergraduate students and first year graduate students. The course contents are multidisciplinary, combining materials from engineering and the biological sciences. The course covers an introduction to the fundamentals of non-equilibrium plasmas, low temperature plasma sources, and cell biology. This is followed by a detailed discussion of the interaction of low temperature plasma with biological cells, both prokaryotes and eukaryotes. Potential applications in medicine such as wound healing, blood coagulation, sterilization, and the killing of various types of cancer cells will be covered. (Offered fall)
Prerequisites: Senior standing

ECE 570 Foundations of Cyber Security (3 Credit Hours)
Course provides an overview of theory, tools and practice of cyber security and information assurance through prevention, detection and modeling of cyber attacks and recovery from such attacks. Techniques for security modeling, attack modeling, risk analysis and cost-benefit analysis are described to manage the security of cyber systems. Fundamental principles of cyber security and their applications for protecting software and information assets of individual computers and large networked systems are explored. Anatomy of some sample attacks designed to compromise confidentiality, integrity and availability of cyber systems are discussed. Cross-listed with MSIM 570. (Offered fall)
Prerequisites: A grade of C or better in ENGN 150 or CS 150 and junior standing or permission of the instructor

ECE 571 Introduction to Solar Cells (3 Credit Hours)
This course is designed to provide the fundamental physics and characteristics of photovoltaic materials and devices. A focus is placed on i) optical interaction, absorption, and design for photovoltaic materials and systems, ii) subsequent energy conversion processes in inorganic/organic semiconductor such as generation, recombination, and charge transport, and iii) photovoltaic testing and measurement techniques to characterize solar cells including contact and series resistance, open circuit voltage, short circuit current density, fill factor, and energy conversion efficiency of photovoltaic devices. (Offered fall)
Prerequisites: ECE 332

ECE 572 Plasma Processing at the Nanoscale (3 Credit Hours)
The science and design of partially ionized plasma and plasma processing devices used in applications such as etching and deposition at the nanoscale. Gas phase collisions, transport parameters, DC and RF glow discharges, the plasma sheath, sputtering, etching, and plasma deposition. (Offered fall)
Prerequisites: ECE 323

ECE 573 Solid State Electronics (3 Credit Hours)
The objective of this course is to understand basic semiconductor devices by understanding semiconductor physics (energy bands, carrier statistics, recombination and carrier drift and diffusion) and to gain an advanced understanding of the physics and fundamental operation of advanced semiconductor devices. Following the initial introductory chapters on semiconductor physics, this course will focus on the theory of p-n junctions, metal-semiconductor Schottky diodes, MOS capacitors, MOS field effect transistors (MOSFET) and bipolar junction transistors (BJTs). (Offered fall)
Prerequisites: ECE 313, ECE 323, ECE 332 and MATH 212

ECE 574 Optical Fiber Communications (3 Credit Hours)
This course introduces seniors and first year graduates to the physics and design of optical fiber communication systems. The topics covered are: electromagnetic waves; optical sources including laser diodes; optical amplifiers; modulators; optical fibers; attenuation and dispersion in optical fibers; photodetectors; optical receivers; noise considerations in optical receivers; optical communication systems. (Offered spring)
Prerequisites: ECE 323

ECE 575 Transportation Data Analytics (3 Credit Hours)
This course presents the basic techniques for transportation data analytics. It will discuss statistical modeling, prominent algorithms, and visualization approaches to analyze both small- and large-scale data sets generated from transportation systems. Practices of using different data for various real-world traffic/transportation applications and decision making will also be discussed., STAT 330 or ECE 304); any programming language such as C, Python or Java is beneficial but not required.
Prerequisites: Basic probability and statistics (e.g

ECE 583 Embedded Systems (3 Credit Hours)
This course covers fundamentals of embedded systems: basic architecture, programming, and design. Topics include processors and hardware for embedded systems, embedded programming and real time operating systems. (Offered fall)
Pre- or corequisite: ECE 346

ECE 595 Topics in Electrical and Computer Engineering (1-3 Credit Hours)
Study of topics in electrical and computer engineering.
Prerequisites: departmental approval

ECE 596 Topics in Electrical and Computer Engineering (1-3 Credit Hours)
Study of topics in electrical and computer engineering.
Prerequisites: departmental approval

ECE 601 Linear Systems (3 Credit Hours)
A comprehensive introduction to the analysis of linear dynamical systems from an input-output and state space point of view. Concepts from linear algebra, numerical linear algebra and linear operator theory are used throughout. Some elements of state feedback design and state estimation are also covered.
Prerequisites: MATH 307

ECE 607 Machine Learning I (3 Credit Hours)
Course provides a practical treatment of design, analysis, implementation and applications of algorithms. Topics include multiple machine learning models: linear models, neural networks, support vector machines, instance-based learning, Bayesian learning, genetic algorithms, ensemble learning, reinforcement learning, unsupervised learning, etc.
Prerequisites: Graduate standing

ECE 611 Numerical Methods in Engineering Analysis (3 Credit Hours)
Course intended to provide graduate students in Electrical and Computer Engineering with a basic knowledge of numerical methods applied to engineering problem-solving process. The course includes the following topics: Introduction to computing (Matlab), Truncation errors and Taylor series, Numerical integration, Solution of non-linear equations, Least-Square regression, Interpolations, Ordinary and partial differential equations, and Finite difference methods. Applications to the area of electrical engineering.
Prerequisites: Graduate standing or advisor's permission (for BS/MS students)

ECE 612 Digital Signal Processing I (3 Credit Hours)
This course will present the fundamentals of digital signal processing. Topics will include frequency domain analysis of discrete-time linear systems, sampling and reconstruction of signals, the Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT), and digital filter design and implementations. Practical applications and examples will be discussed. Problem solving using MATLAB is required.
Prerequisites: ECE 381 or equivalent

ECE 623 Electromagnetism (3 Credit Hours)
Review of electrostatic and magnetostatic concepts, time varying field, Maxwell's equations, plane wave propagation in various media, transmission lines, optical wave guides, resonant cavities, simple radiation systems, and their engineering applications.
Prerequisites: ECE 323 or equivalent

ECE 642 Computer Networking (3 Credit Hours)
The course is based on the ISO (International Standard Organization) OSI (Open Systems Interconnection) reference model for computer networks. A focus is placed on the analysis of protocols at different layers, network architectures, and networking systems performance analysis. Current topic areas include LANs, MANs, TCP/IP networks, mobile communications, and ATM.
Prerequisites: ECE 455 or ECE 555 or permission of the instructor

ECE 643 Computer Architecture Design (3 Credit Hours)
Digital computer design principles. The course focuses on design of state-of-the-art computing systems. An emphasis is placed on superscalar architectures focusing on the pipelining and out-of-order instruction execution operations.
Prerequisites: ECE 443 or ECE 543

ECE 648 Advanced Digital Design (3 Credit Hours)
This course introduces methods for using high level hardware description language such as VHDL and/or Verilog for the design of digital architecture. Topics include top-down design approaches, virtual prototyping, design abstractions, hardware modeling techniques, algorithmic and register level design, synthesis methods, and application decomposition issues. Final design project is required.
Prerequisites: ECE 341

ECE 651 Statistical Analysis and Simulation (3 Credit Hours)
An introduction to probabilistic and statistical techniques for analysis of signals and systems. This includes a review of probability spaces, random variables, and random processes. Analysis and simulation of systems with random parameters and stochastic inputs are considered.
Prerequisites: MATH 312 and one undergraduate course in probability or statistics or permission of instructor

ECE 652 Wireless Communications Networks (3 Credit Hours)
Fundamental concepts in wireless communication systems and networks: radio waveform propagation modeling (free-space, reflections and multipath, fading, diffraction and Doppler effects); physical and statistical models for wireless channels; modulation schemes for wireless communications and bandwidth considerations; diversity techniques; MIMO systems and space-time coding; multiuser systems and multiple access techniques (TDMA, FDMA. CDMA); spread spectrum and multiuser detection; introduction to wireless networking and wireless standards; current and emerging wireless technologies.
Prerequisites: ECE 451 or ECE 551 or permission of instructor

ECE 667 Cooperative Education (1-3 Credit Hours)
Student participation for credit based on academic relevance of the work experience, criteria, and evaluative procedures as formally determined by the department and the Cooperative Education/Career Development Services program prior to the semester in which the work experience is to take place.

ECE 668 Internship (1-3 Credit Hours)
Academic requirements will be established by the department and will vary with the amount of credit desired. Allows students an opportunity to gain short duration career related experience. Meant to be used for one-time experience. Work may or may not be paid. Project is completed during the term.
Prerequisites: approval by department and Career Development Services

ECE 669 Practicum (1-3 Credit Hours)
Academic requirements will be established by the department and will vary with the amount of credit desired. Allows students an opportunity to gain short duration career related experience. Student is usually already employed - this is an additional project in the organization.
Prerequisites: approval by department and Career Development Services

ECE 695 Topics in Electrical or Computer Engineering (3 Credit Hours)
This course will be offered as needed, depending upon the need to introduce special subjects to target specific areas of master's-level specializations in electrical or computer engineering.

ECE 698 Master's Project (1-3 Credit Hours)
Individual project directed by the student's professor in major area of study.

ECE 699 Thesis (1-9 Credit Hours)
Directed research for the master's thesis.
Prerequisites: departmental approval

ECE 731 Graduate Seminar (1 Credit Hour)
Graduate seminar presentations concerning technical topics of current interest given by faculty and invited speakers.
Prerequisites: graduate standing

ECE 742 Computer Communication Networks (3 Credit Hours)
This is an advanced level course in data communications. A focus is placed on the analysis, modeling, and control of computer communication systems. Topics include packet switched networks, circuit switched networks, ATM networks, network programming, network control and performance analysis, network security, and wireless sensor networks.
Prerequisites: ECE 642 or permission of instructor

ECE 751 Computational and Statistical Methods in Biomedical Engineering (3 Credit Hours)
This course covers the theoretical foundation and application of commonly used techniques in biomedical engineering. Topics include linear algebra, partial differential equations, regression analysis, applied probabilities, multivariate distributions, Bayesian statistics, hypothesis tests, multiple comparisons, ANOVA, solution of non-linear equations, numerical methods and optimization. Programming software will be used to perform simulations and analyze biomedical data.

ECE 754 Advanced Bioelectrics (3 Credit Hours)
Bioelectrics is a new field encompassing both the science and technology of applying electrical stimuli to biological systems. This course covers the pulsed power technology that is required to generate electrical stimuli as well as the biological responses they evoke in cells and tissues. Particular emphasis is placed on the medical applications of bioelectrics, including tumor ablation, gene electrotransfer, wound healing, decontamination with cold plasma, and treatment of cardiac arrhythmias.
Prerequisites: ECE 454 or ECE 554 or BIOE 454 or BIOE 554

ECE 755 Biomembranes and Ion Channels (3 Credit Hours)
This course will give an overview of the structure and dynamics of biomembranes, the ion channels that are embedded in them, and the electrical properties of biomembranes. Topics include molecular dynamics modeling of biomembranes, membrane damage and repair, ion channel dynamics and their experimental assessment using patch clamping, and excitability in neurons and cardiomyocytes.
Prerequisites: ECE 454 or ECE 554 or BIOL 523

ECE 762 Digital Control Systems (3 Credit Hours)
Mathematical representation, analysis, and design of discrete-time and sampled-data control systems. Topics include transfer function and state space representations, stability, the root locus method, frequency response methods, and state feedback.
Prerequisites: ECE 381, ECE 461 or ECE 561, and ECE 601 or permission of instructor

ECE 763 Multivariable Control Systems (3 Credit Hours)
A comprehensive introduction to techniques applicable in control of complex systems with multiple inputs and outputs. Both the frequency domain and state variable approaches are utilized. Special topics include robust and optimal control.
Prerequisites: ECE 461 or ECE 561 and ECE 601 or permission of instructor

ECE 766 Nonlinear Control Systems (3 Credit Hours)
An introduction to mathematical representation, analysis, and design of nonlinear control systems. Topics include phase-plane analysis, Lyapunov stability theory for autonomous and nonautonomous systems, formal power series methods and differential geometric design techniques.
Prerequisites: ECE 461 or ECE 561 and ECE 601 or permission of instructor

ECE 772 Fundamentals of Solar Cells (3 Credit Hours)
The course provides an overview of the fundamentals of solar cell technologies, design, and operation. The course is designed for graduate students in Engineering and Science interested in the field of alternative energy. The course objectives are to make sure each student: understands the various forms of alternative energies, understands solar cell design, understands solar cell operation, and acquires knowledge of the various solar cells technologies. The topics to be covered include: Alternative energies; Worldwide status of Photovoltaics; Solar irradiance; Review of semiconductor properties; Generation, recombination; Basic equations of device physics; p-n junction diodes; Ideal solar cells; Efficiency limits; Efficiency losses and measurements; Module fabrication; c-Si technology; classical; Photovoltaic systems; Design of stand-alone system; Residential PV systems.
Prerequisites: Graduate standing in Engineering and Science

ECE 773 Introduction to Nanotechnologies (3 Credit Hours)
This course will introduce the rapidly emerging field of nanotechnology with special focus on underlying principles and applications relevant to the nanoscale dimensions. Specifically, this course will cover (1) the basic principles related to synthesis and fabrication of nanomaterials and nanostructures, (2) zero-, one-, two- and three-dimensional nanostructures, (3) characterization and properties of nanomaterials, and (4) application of nanoscale devices.
Prerequisites: graduate standing in Engineering and Science

ECE 774 Semiconductor Characterization (3 Credit Hours)
Introduction of basic methods for semiconductor material and device characterization. Topics include resistivity, carrier doping concentration, contact resistance, Schottky barrier height, series resistance, channel length, threshold voltage, mobility, oxide and interface trapped charge, deep level impurities, carrier lifetime, and optical, chemical and physical characterization.
Prerequisites: ECE 473 or ECE 573 or equivalent

ECE 775 Non-thermal Plasma Engineering (3 Credit Hours)
This course covers the fundamental principals governing low temperature plasma discharges and their applications. First the fundamental properties of plasmas are introduced. These include the kinetic theory of gases, collisional processes, and plasma sheaths. Then in-depth coverage of the physical mechanisms underlying the operation of non-equilibrium plasma discharges is presented, including important characteristics such as their ignition, evolution, and eventual quenching. Finally, practical applications of non-thermal plasmas, including applications in biology and medicine, are presented.
Prerequisites: graduate standing

ECE 777 Semiconductor Process Technology (3 Credit Hours)
Theory, design and fabrication of modern integrated circuits that consist of nano scale devices and materials. Topics include crystal growth and wafer preparation process including epitaxy, thin film deposition, oxidation, diffusion, ion implantation, lithography, dry etching, VLSI process integration, diagnostic assembly and packaging, yield and reliability.
Prerequisites: ECE 473 or ECE 573

ECE 780 Machine Learning II (3 Credit Hours)
Advanced topics in machine learning and pattern recognition systems. Data reduction techniques including principle component analysis, independent component analysis and manifold learning. Introduction to sparse coding and deep learning for data representation and feature extraction.
Prerequisites: ECE 607 or equivalent

ECE 782 Digital Signal Processing II (3 Credit Hours)
Review of time domain and frequency domain analysis of discrete time signals and systems. Fast Fourier Transforms, recursive and non-recursive digital filter analysis and design, multirate signal processing, optimal linear filters, and power spectral estimation.
Prerequisites: ECE 612 or equivalent

ECE 783 Digital Image Processing (3 Credit Hours)
Principles and techniques of two-dimensional processing of images. Concepts of scale and spatial frequency. Image filtering in spatial and transform domains. Applications include image enhancement and restoration, image compressing, and image segmentation for computer vision.
Prerequisites: ECE 381 or ECE 612 or ECE 782 or ECE 882

ECE 784 Computer Vision (3 Credit Hours)
Principles and applications of computer vision, advanced image processing techniques as applied to computer vision problems, shape analysis and object recognition.
Prerequisites: graduate standing

ECE 787 Digital Communications (3 Credit Hours)
Fundamental concepts of digital communication and information transmission: information sources and source coding; orthonormal expansions of signals, basis functions, and signal space concepts; digital modulation techniques including PAM, QAM, PSK and FSK; matched filters, demodulation and optimal detection of symbols and sequences; bandwidth; mathematical modeling of communication channels; channel capacity.
Prerequisites: ECE 451/ECE 551 or equivalent or permission of the instructor

ECE 795 Topics in Electrical and Computer Engineering (3 Credit Hours)
Topics in Electrical and Computer Engineering
Prerequisites: departmental approval

ECE 796 Topics in Electrical and Computer Engineering (3 Credit Hours)
Study of selected topics in Electrical and Computer Engineering.
Prerequisites: departmental approval

ECE 797 Independent Study (1-3 Credit Hours)
This course allows students to develop specialized expertise by independent study (supervised by a faculty member).
Prerequisites: departmental approval

ECE 831 Graduate Seminar (1 Credit Hour)
Graduate seminar presentations concerning technical topics of current interest given by faculty and invited speakers.

ECE 842 Computer Communication Networks (3 Credit Hours)
This is an advanced level course in data communications. A focus is placed on the analysis, modeling, and control of computer communication systems. Topics include packet switched networks, circuit switched networks, ATM networks, network programming, network control and performance analysis, network security, and wireless sensor networks.
Prerequisites: ECE 642 or permission of instructor

ECE 851 Computational and Statistical Methods in Biomedical Engineering (3 Credit Hours)
This course covers the theoretical foundation and application of commonly used techniques in biomedical engineering. Topics include linear algebra, partial differential equations, regression analysis, applied probabilities, multivariate distributions, Bayesian statistics, hypothesis tests, multiple comparisons, ANOVA, solution of non-linear equations, numerical methods and optimization. Programming software will be used to perform simulations and analyze biomedical data.

ECE 854 Advanced Bioelectrics (3 Credit Hours)
Bioelectrics is a new field encompassing both the science and technology of applying electrical stimuli to biological systems. This course covers the pulsed power technology that is required to generate electrical stimuli as well as the biological responses they evoke in cells and tissues. Particular emphasis is placed on the medical applications of bioelectrics, including tumor ablation, gene electrotransfer, wound healing, decontamination with cold plasma, and treatment of cardiac arrhythmias.
Prerequisites: ECE 454 or ECE 554 or BIOE 454 and BIOE 554

ECE 855 Biomembranes and Ion Channels (3 Credit Hours)
This course will give an overview of the structure and dynamics of biomembranes, the ion channels that are embedded in them, and the electrical properties of biomembranes. Topics include molecular dynamics modeling of biomembranes, membrane damage and repair, ion channel dynamics and their experimental assessment using patch clamping, and excitability in neurons and cardiomyocytes.
Prerequisites: ECE 454 or ECE 554 or BIOL 523

ECE 862 Digital Control Systems (3 Credit Hours)
Mathematical representation, analysis, and design of discrete-time and sampled-data control systems. Topics include transfer function and state space representations, stability, the root locus method, frequency response methods, and state feedback.
Prerequisites: ECE 381, ECE 461 or ECE 561, and ECE 601 or permission of instructor

ECE 863 Multivariable Control Systems (3 Credit Hours)
A comprehensive introduction to techniques applicable in control of complex systems with multiple inputs and outputs. Both the frequency domain and state variable approaches are utilized. Special topics include robust and optimal control.
Prerequisites: ECE 461 or ECE 561 and ECE 601 or permission of the instructor

ECE 866 Nonlinear Control Systems (3 Credit Hours)
An introduction to mathematical representation, analysis, and design of nonlinear control systems. Topics include phase-plane analysis, Lyapunov stability theory for autonomous and nonautonomous systems, formal power series methods and differential geometric design techniques.
Prerequisites: ECE 461 or ECE 561 and ECE 601 or permission of instructor

ECE 872 Fundamentals of Solar Cells (3 Credit Hours)
The course provides an overview of the fundamentals of solar cell technologies, design, and operation. The course is designed for graduate students in Engineering and Science interested in the field of alternative energy. The course objectives are to make sure each student: understands the various forms of alternative energies, understands solar cell design, understands solar cell operation, and acquires knowledge of the various solar cells technologies. The topics to be covered include: Alternative energies; Worldwide status of Photovoltaics; Solar irradiance; Review of semiconductor properties; Generation, recombination; Basic equations of device physics; p-n junction diodes; Ideal solar cells; Efficiency limits; Efficiency losses and measurements; Module fabrication; c-Si technology; classical; Photovoltaic systems; Design of stand-alone system; Residential PV systems.
Prerequisites: Graduate standing in Engineering and Science

ECE 873 Introduction to Nanotechnologies (3 Credit Hours)
This course will introduce the rapidly emerging field of nanotechnology with special focus on underlying principles and applications relevant to the nanoscale dimensions. Specifically, this course will cover (1) the basic principles related to synthesis and fabrication of nanomaterials and nanostructures, (2) zero-, one-, two- and three-dimensional nanostructures, (3) characterization and properties of nanomaterials, and (4) application of nanoscale devices.
Prerequisites: graduate standing in Engineering and Science

ECE 874 Semiconductor Characterization (3 Credit Hours)
Introduction of basic methods for semiconductor material and device characterization. Topics include resistivity, carrier doping concentration, contact resistance, Schottky barrier height, series resistance, channel length, threshold voltage, mobility, oxide and interface trapped charge, deep level impurities, carrier lifetime, and optical, chemical and physical characterization.
Prerequisites: ECE 473 or ECE 573 or equivalent

ECE 875 Non-thermal Plasma Engineering (3 Credit Hours)
This course covers the fundamental principals governing low temperature plasma discharges and their applications. First the fundamental properties of plasmas are introduced. These include the kinetic theory of gases, collisional processes, and plasma sheaths. Then in-depth coverage of the physical mechanisms underlying the operation of non-equilibrium plasma discharges is presented, including important characteristics such as their ignition, evolution, and eventual quenching. Finally, practical applications of non-thermal plasmas, including applications in biology and medicine, are presented.
Prerequisites: graduate standing

ECE 877 Semiconductor Process Technology (3 Credit Hours)
Theory, design and fabrication of modern integrated circuits that consist of nano scale devices and materials. Topics include crystal growth and wafer preparation process including epitaxy, thin film deposition, oxidation, diffusion, ion implantation, lithography, dry etching, VLSI process integration, diagnostic assembly and packaging, yield and reliability.
Prerequisites: ECE 473 or ECE 573

ECE 880 Machine Learning II (3 Credit Hours)
Advanced topics in machine learning and pattern recognition systems. Data reduction techniques including principle component analysis, independent component analysis and manifold learning. Introduction to sparse coding and deep learning for data representation and feature extraction.
Prerequisites: ECE 607 or equivalent

ECE 882 Digital Signal Processing II (3 Credit Hours)
Review of time domain and frequency domain analysis of discrete time signals and systems. Fast Fourier Transforms, recursive and non-recursive digital filter analysis and design, multirate signal processing, optimal linear filters, and power spectral estimation.
Prerequisites: ECE 612 or equivalent

ECE 883 Digital Image Processing (3 Credit Hours)
Principles and techniques of two-dimensional processing of images. Concepts of scale and spatial frequency. Image filtering in spatial and transform domains. Applications include image enhancement and restoration, image compressing, and image segmentation for computer vision.
Prerequisites: ECE 381 or ECE 612 or ECE 782 or ECE 882

ECE 884 Computer Vision (3 Credit Hours)
Principles and applications of computer vision, advanced image processing techniques as applied to computer vision problems, shape analysis and object recognition.
Prerequisites: Graduate standing

ECE 887 Digital Communications (3 Credit Hours)
Fundamental concepts of digital communication and information transmission: information sources and source coding; orthonormal expansions of signals, basis functions, and signal space concepts; digital modulation techniques including PAM, QAM, PSK and FSK; matched filters, demodulation and optimal detection of symbols and sequences; bandwidth; mathematical modeling of communication channels; channel capacity.
Prerequisites: ECE 451/ECE 551 or equivalent or permission of the instructor

ECE 892 Doctor of Engineering Project (1-12 Credit Hours)
Directed individual study applying advanced level technical knowledge to identify, formulate, and solve a complex, novel problem in electrical and computer engineering.

ECE 895 Topics in Electrical and Computer Engineering (3 Credit Hours)
Topics in Electrical and Computer Engineering.
Prerequisites: departmental approval

ECE 896 Topics in Electrical and Computer Engineering (3 Credit Hours)
Topics in Electrical and Computer Engineering

ECE 897 Independent Study (1-3 Credit Hours)
This course allows students to develop specialized expertise by independent study (supervised by a faculty member)
Prerequisites: departmental approval

ECE 899 Dissertation Research (1-9 Credit Hours)
Directed research for the doctoral dissertation.
Prerequisites: departmental approval

ECE 998 Master's Graduate Credit (1 Credit Hour)
This course is a pass/fail course for master's students in their final semester. It may be taken to fulfill the registration requirement necessary for graduation. All master's students are required to be registered for at least one graduate credit hour in the semester of their graduation.

ECE 999 Doctoral Graduate Credit (1 Credit Hour)
This course is a pass/fail course doctoral students may take to maintain active status after successfully passing the candidacy examination. All doctoral students are required to be registered for at least one graduate credit hour every semester until their graduation.

Modeling and Simulation (MSIM)

MSIM 506 Introduction to Distributed Simulation (3 Credit Hours)
An introduction to distributed simulation. Topics include motivation for using distributed simulation, distributed simulation architectures, time management issues, and distributed simulation approaches. Current standards for distributed simulation are presented.
Prerequisites: MSIM 331 or ECE 348

MSIM 508 Introduction to Game Development (3 Credit Hours)
An introductory course focused on game development theory and modern practices with emphasis on educational game development. Topics include game architecture, computer graphics theory, user interaction, audio, high level shading language, animation, physics, and artificial intelligence. The developed games can run on a variety of computer, mobile, and gaming platforms.
Prerequisites: Requires an understanding of physics and CS 361, MSIM 331, or ECE 348

MSIM 510 Model Engineering (3 Credit Hours)
The goal of this course is to develop understanding of the various modeling paradigms appropriate for capturing system behavior and conducting digital computer simulation of many types of systems. The techniques and concepts discussed typically include UML, concept graphs, Bayesian nets, Markov models, Petri nets, system dynamics, Bond graphs, etc. Students will report on a particular technique and team to implement a chosen system model. (cross-listed with ECE 510)

MSIM 516 Cyber Defense Fundamentals (3 Credit Hours)
This course focuses on cybersecurity theory, information protection and assurance, and computer systems and networks security. The objectives are to understand the basic security models and concepts, learn fundamental knowledge and tools for building, analyzing, and attacking modern security systems, and gain hands-on experience in cryptographic algorithms, security fundamental principles, and Internet security protocol and standards. Cross-listed with ECE 516.

MSIM 519 Cyber Physical Systems Security (3 Credit Hours)
Cyber Physical Systems (CPS) integrate computing, networking, and physical processes. The objectives of this course are to learn the basic concepts, technologies and applications of CPS, understand the fundamental CPS security challenges and national security impact, and gain hands-on experience in CPS infrastructures, critical vulnerabilities, and practical countermeasures. Cross-listed with ECE 519.

MSIM 541 Computer Graphics and Visualization (3 Credit Hours)
The course provides a practical treatment of computer graphics and visualization with emphasis on modeling and simulation applications. It covers digital image and signal processing basics such as sampling and discrete Fourier transform, computer graphics fundamentals, visualization principles, and software architecture for visualization in modeling and simulation. Written communication and information literacy skills are stressed in this course. (Cross listed with ECE 506.) (Offered fall)
Prerequisites: a grade of C or better in CS 361, or ECE 348, or MSIM 331, or MSIM 603

MSIM 551 Analysis for Modeling and Simulation (3 Credit Hours)
An introduction to analysis techniques appropriate to the conduct of modeling and simulation studies. Topics include input modeling, random number generation, output analysis, variance reduction techniques, and experimental design. In addition, techniques for verification & validation are introduced. Course concepts are applied to real systems and data.
Prerequisites: MSIM 205 or ECE 306 and STAT 330 or ECE 304

MSIM 562 Introduction to Medical Image Analysis (3 Credit Hours)
Introduction to basic concepts in medical image analysis. Medical image registration, segmentation, feature extraction, and classification are discussed. Basic psychophysics, fundamental ROC analysis and FROC methodologies are covered. Cross-listed with ECE 462/ECE 562.

MSIM 563 Design and Modeling of Autonomous Robotic Systems (3 Credit Hours)
Course focuses on autonomous robotics systems with emphasis on using modeling and simulation (M&S) for system level design and testing. Fundamental concepts associated with autonomous robotic systems are discussed. Course topics include: robotic control, architectures, and sensors as well as more advanced concepts such as error propagation, localization, mapping and autonomy. Design strategies that leverage M&S to accelerate the development and testing of sophisticated autonomous robotic algorithms for individual or teams of robots are covered.
Prerequisites: CS 150 or ENGN 150

MSIM 570 Foundations of Cyber Security (3 Credit Hours)
Course provides an overview of theory, tools and practice of cyber security and information assurance through prevention, detection and modeling of cyber attacks and recovery from such attacks. Techniques for security modeling, attack modeling, risk analysis and cost-benefit analysis are described to manage the security of cyber systems. Fundamental principles of cyber security and their applications for protecting software and information assets of individual computers and large networked systems are explored. Anatomy of some sample attacks designed to compromise confidentiality, integrity and availability of cyber systems are discussed.
Prerequisites: CS 150 or ENGN 150

MSIM 574 Transportation Data Analytics (3 Credit Hours)
This course presents the basic techniques for transportation data analytics. It will discuss statistical modeling, prominent algorithms, and visualization approaches to analyze both small- and large-scale data sets generated from transportation systems. Practices of using different data for various real-world traffic/transportation applications and decision making will also be discussed., STAT 330 or ECE 304); any programming language such as C, Python or Java is beneficial but not required.
Prerequisites: Basic probability and statistics (e.g

MSIM 580 Introduction to Artificial Intelligence (3 Credit Hours)
Introduction to concepts, principles, challenges, and research in major areas of artificial intelligence. Areas of discussion include: natural language and vision processing, machine learning, machine logic and reasoning, robotics, expert and mundane systems. Laboratory work required.
Prerequisites: Instructor approval

MSIM 595 Topics in Modeling and Simulation Engineering (3 Credit Hours)
Special topics of interest with emphasis placed on recent developments in modeling and simulation engineering.

MSIM 596 Topics in Modeling and Simulation Engineering (1-3 Credit Hours)
Special topics of interest with emphasis placed on the recent developments in modeling and simulation engineering.
Prerequisites: permission of the instructor

MSIM 597 Independent Study in Modeling and Simulation Engineering (3 Credit Hours)
Individual analytical, computational, and/or experimental study in an area selected by the student. Supervised and approved by the advisor.

MSIM 601 Introduction to Modeling and Simulation (3 Credit Hours)
Modeling and simulation (M&S) discipline surveyed at an overview level of detail. Basic terminology, modeling methods, and simulation paradigms are introduced. Applications of M&S in various disciplines are discussed. The course provides a general conceptual framework for those interested in using M&S and for further studies in M&S. Not open to MSVE degree seeking students.
Prerequisites: graduate standing; undergraduate exposure to calculus and probability & statistics

MSIM 602 Simulation Fundamentals (3 Credit Hours)
An introduction to the modeling and simulation discipline. Introduction to discrete event simulation (DES) including simulation methodology, input data modeling, output data analysis, and an overview of DES tools. Introduction to continuous simulation (CS) including simulation methodology, differential equation models, numerical solution techniques, and an overview of CS tools.
Prerequisites: graduate standing; undergraduate preparation in calculus and probability & statistics; and computer literacy

MSIM 603 Simulation Design (3 Credit Hours)
Course develops the computer software skills necessary for the design and development of simulation software. Topics covered include software architectures, software engineering, software design, object-oriented programming, abstract data types and classes, data structures, algorithms, and testing and debugging techniques. Software design and development of simulation systems (discrete-event, continuous, and Monte Carlo) are emphasized.
Prerequisites: MSIM 602 and an introductory computer programming course

MSIM 607 Machine Learning I (3 Credit Hours)
Course provides a practical treatment of design, analysis, implementation and applications of algorithms. Topics include multiple learning models: linear models, neural networks, support vector machines, instance-based learning, Bayesian learning, genetic algorithms, ensemble learning, reinforcement learning, unsupervised learning, etc. (Cross listed with ECE 607)

MSIM 660 System Architecture and Modeling (3 Credit Hours)
Students will learn the essential aspects of the system architecture paradigm through environment and analysis of multiple architecture framework and enterprise engineering, such as IDEFO, TOGAF, DODAF and OPM. Emphasis on system modeling and enterprise engineering. (Cross listed with ENMA 660)

MSIM 667 Cooperative Education (1-3 Credit Hours)
Available for pass/fail grading only. Student participation for credit based on academic relevance of the work experience, criteria, and evaluation procedures as formally determined by the program and the Cooperative Education/Career Development Services program prior to the semester in which the work experience is to take place.

MSIM 668 Internship (1-3 Credit Hours)
Academic requirements will be established by the department and will vary with the amount of credit desired. Allows students an opportunity to gain short duration career-related experience.
Prerequisites: Approval by department and Career Development Services

MSIM 669 Practicum (1-3 Credit Hours)
Academic requirements will be established by the graduate program director and will vary with the amount of credit desired. Allows students an opportunity to gain short-duration career related experience. Student is usually employed–this is an additional project beyond the duties of the student's employment.

MSIM 670 Cyber Systems Engineering (3 Credit Hours)
This course provides an overview of functioning of cyber systems including how a computer interacts with the outside world. The composition of critical infrastructure and functioning of different engineered systems that form critical infrastructure are discussed. Mutual dependence and interactions between cyber systems and other engineered systems and the resulting security risks are also explored. (Cross-listed with ENMA 670.)

MSIM 673 Threat Modeling and Risk Analysis (3 Credit Hours)
This course discusses how to develop cyber threat models using attack graphs/trees, STRIDE, Universal Modeling Language (UML), attack graphs/trees and common of risk analysis tools. Course also discusses the need for quantitative security analysis and formal validation of security models and basic principles of formal model validation. (Cross-listed with ENMA 673.)

MSIM 695 Topics in Modeling and Simulation (3 Credit Hours)
Special topics of interest with emphasis placed on recent developments in modeling and simulation.

MSIM 697 Independent Study in Modeling and Simulation (3 Credit Hours)
Individual study selected by the student. Supervised and approved by a faculty member with the approval of the graduate program director.
Prerequisites: permission of instructor or graduate program director

MSIM 699 Thesis (1-6 Credit Hours)
Research leading to the Master of Science thesis.
Prerequisites: permission of instructor and graduate program director

MSIM 702 Systemic Decision Making (3 Credit Hours)
As machine age problems have given way to systems age messes, the underlying complexity associated with understanding these situations has increased exponentially. Accordingly, the methods we use to address these situations must evolve as well. This course will introduce students to a method for thinking holistically about problems and messes conceptually founded in systems theory. This paradigm, known as systemic thinking, will be contrasted with traditional systematic thinking, and practical guidelines for the deployment of a systemic thinking approach will be provided. This paradigm will increase the student's ability to make rational decisions in complex environments. (Cross listed with ENMA 702).

MSIM 703 Optimization Methods (3 Credit Hours)
Covers advanced methods in Operations Research and Optimization. Focus will be on developing models and their applications in different domains including manufacturing and service. Modern optimization tools will be used to implement models for case studies, projects and research papers. The knowledge of programming and spreadsheets is expected. Contact instructor for more details. (Cross-listed with ENMA 703).

MSIM 711 Finite Element Analysis (3 Credit Hours)
The purpose of the course is to provide an understanding of the finite element method (FEM) as derived from an integral formulation perspective. The course will demonstrate the solutions of (1-D and 2-D) continuum mechanics problems such as solid mechanics, fluid mechanics and heat transfer.
Prerequisites: permission of the instructor

MSIM 715 High Performance Computing and Simulations (3 Credit Hours)
Introduction to modern high performance computing platforms including top supercomputers and accelerators. Discussion of parallel architectures, performance, programming models, and software development issues. Case studies of scientific and engineering simulations will be explored. Students will have an opportunity to work on parallelization of problems from their research areas. Project presentations are required.

MSIM 722 Cluster Parallel Computing (3 Credit Hours)
This course provides detailed numerical step-by-step procedures to exploit parallel and sparse computation under MPI (Message Passing Interface) computer environments. Large-scale engineering/science applications are emphasized. Simultaneous linear equations are discussed.

MSIM 725 Principles of Combat Modeling and Simulation (3 Credit Hours)
Principles of combat modeling and simulation. Introduction including history, basic definitions, and best practice. Algorithms for modeling movement, sensing effects and behavior. Overview of modern combat models. Interoperability and integration into operational environments.
Prerequisites: MSIM 603

MSIM 730 Simulation Formalisms (3 Credit Hours)
The focus of the course is on identification and investigation of mathematical and logical structures that form the foundation for computational simulation. Topics include: foundations of simulation theory in logic, discrete mathematics, and computability; simulation formalisms, including DEVS; interoperability protocols; and computational complexity.

MSIM 741 Principles of Visualization (3 Credit Hours)
Well-designed graphical media capitalizes on human facilities for processing visual information and thereby improves comprehension, memory, inference, and decision making. This course teaches techniques and algorithms for creating effective visualizations based on principles and techniques from graphic design, visual art, perceptual psychology and cognitive science. Both users and developers of visualization tools and systems will benefit from this course.

MSIM 742 Synthetic Environments (3 Credit Hours)
The course covers the theory and techniques for building effective and efficient synthetic environments for modeling and simulation applications. Topics include physics, artificial intelligence, virtual reality, and advanced modeling and rendering. The emphasis is on producing visually realistic synthetic environments based on effective approximations of physics and other related principles.
Prerequisites: MSIM 541 or equivalent

MSIM 751 Advanced Analysis for Modeling and Simulation (3 Credit Hours)
An introduction to stochastic dependence and Bayesian analysis techniques for conducting modeling and simulation studies. Topics include: measures of dependence, common multivariate distributions, sampling from multivariate distributions, elementary time series models and Bayesian statistics.
Prerequisites: MSIM 451 or MSIM 551

MSIM 762 Applied Medical Image Analysis (3 Credit Hours)
Course explores hands-on exposure to state-of-the-art algorithms in medical image analysis, which builds on open-source software (Insight Segmentation and Registration Toolkit - ITK), as well as the principles of medical image acquisition in the modalities of clinical interest. Medical imaging modalities - X-rays, CT, and MRI/ITK image pipeline; image enhancement, feature detection; segmentation - basic techniques, feature-based classification and clustering, graph cuts, active contour and surface models; surface and volume meshing; registration - transformations, similarity criteria; shape and appearance models are all explored and discussed in this course.
Prerequisites: Knowledge of C++ and object-oriented programming

MSIM 772 Modeling Global Events (3 Credit Hours)
Modeling Global Events introduces modeling and simulation as a tool for expanding our understanding of events that have shaped the global environment of the 21st century. Students will review real-world case studies and then analyze these case studies via system dynamics, agent-based, social network, and game theory modeling paradigms. This course is designed to develop empirical research skills, conceptual modeling expertise, and model construction. Students will understand how to analyze, verify, and validate a model.

MSIM 774 Transportation Network Flow Models (3 Credit Hours)
This course provides a rigorous introduction to transportation network modeling, with special emphasis on network equilibrium problems. Topics include: elementary graph theory, shortest path problem nonlinear optimization, optimization of univariate functions, deterministic and stochastic user equilibrium. (Cross-listed with CEE 774).

MSIM 775 Transportation Network Algorithms (3 Credit Hours)
Fundamental models and algorithms in optimization, stochastic modeling and parallel computing will be discussed and illustrated with transportation applications. (Cross-listed with CEE 775)

MSIM 776 Simulation Modeling in Transportation Networks (3 Credit Hours)
Principles of simulation modeling, microscopic, mesoscopic, and macroscopic traffic simulation models. Course explores diver behavior in networks, calibration and validation of traffic simulation models, and use of traffic simulation software. (Cross-listed with CEE 776)

MSIM 780 Machine Learning II (3 Credit Hours)
Advanced topics in machine learning and pattern recognition systems. Data reduction techniques including principle component analysis, independent component analysis and manifold learning. Introduction to sparse coding and deep learning for data representation and feature extraction. (Cross-listed with ECE 780)
Prerequisites: MSIM 607 or equivalent

MSIM 795 Topics in Modeling and Simulation (3 Credit Hours)
Special topics of interest with emphasis placed on recent developments in modeling and simulation.

MSIM 797 Independent Study in Modeling and Simulation (3 Credit Hours)
Individual study selected by the student. Supervised and approved by a faculty member with the approval of the graduate program director.
Prerequisites: permission of instructor or graduate program director

MSIM 802 Systemic Decision Making (3 Credit Hours)
As machine age problems have given way to systems age messes, the underlying complexity associated with understanding these situations has increased exponentially. Accordingly, the methods we use to address these situations must evolve as well. This course will introduce students to a method for thinking holistically about problems and messes conceptually founded in systems theory. This paradigm, known as systemic thinking, will be contrasted with traditional systematic thinking, and practical guidelines for the deployment of a systemic thinking approach will be provided. This paradigm will increase the student's ability to make rational decisions in complex environments. (Cross listed with ENMA 802).

MSIM 803 Optimization Methods (3 Credit Hours)
Covers advanced methods in Operations Research and Optimization. Focus will be on developing models and their applications in different domains including manufacturing and service. Modern optimization tools will be used to implement models for case studies, projects and research papers. The knowledge of programming and spreadsheets is expected. Contact instructor for more details. (Cross-listed with ENMA 803).

MSIM 811 Finite Element Analysis (3 Credit Hours)
The purpose of the course is to provide an understanding of the finite element method (FEM) as derived from an integral formulation perspective. The course will demonstrate the solutions of (1-D and 2-D) continuum mechanics problems such as solid mechanics, fluid mechanics and heat transfer.
Prerequisites: permission of the instructor

MSIM 815 High Performance Computing and Simulations (3 Credit Hours)
Introduction to modern high performance computing platforms including top supercomputers and accelerators. Discussion of parallel architectures, performance, programming models, and software development issues. Case studies of scientific and engineering simulations will be explored. Students will have an opportunity to work on parallelization of problems from their research areas. Project presentations are required.

MSIM 822 Cluster Parallel Computing (3 Credit Hours)
This course provides detailed numerical step-by-step procedures to exploit parallel and sparse computation under MPI (Message Passing Interface) computer environments. Large-scale engineering/science applications are emphasized. Simultaneous linear equations are discussed.

MSIM 825 Principles of Combat Modeling and Simulation (3 Credit Hours)
Principles of combat modeling and simulation. Introduction including history, basic definitions, and best practice. Algorithms for modeling movement, sensing effects and behavior. Overview of modern combat models. Interoperability and integration into operational environments.
Prerequisites: MSIM 603

MSIM 830 Simulation Formalisms (3 Credit Hours)
The focus of the course is on identification and investigation of mathematical and logical structures that form the foundation for computational simulation. Topics include: foundations of simulation theory in logic, discrete mathematics, and computability; simulation formalisms, including DEVS; interoperability protocols; and computational complexity.

MSIM 841 Principles of Visualization (3 Credit Hours)
Well-designed graphical media capitalizes on human facilities for processing visual information and thereby improves comprehension, memory, inference, and decision making. This course teaches techniques and algorithms for creating effective visualizations based on principles and techniques from graphic design, visual art, perceptual psychology and cognitive science. Both users and developers of visualization tools and systems will benefit from this course.

MSIM 842 Synthetic Environments (3 Credit Hours)
The course covers the theory and techniques for building effective and efficient synthetic environments for modeling and simulation applications. Topics include physics, artificial intelligence, virtual reality, and advanced modeling and rendering. The emphasis is on producing visually realistic synthetic environments based on effective approximations of physics and other related principles.
Prerequisites: MSIM 541 or equivalent

MSIM 851 Advanced Analysis for Modeling and Simulation (3 Credit Hours)
An introduction to stochastic dependence and Bayesian analysis techniques for conducting modeling and simulation studies. Topics include: measures of dependence, common multivariate distributions, sampling from multivariate distributions, elementary time series models and Bayesian statistics.
Prerequisites: MSIM 451 or MSIM 551

MSIM 862 Applied Medical Image Analysis (3 Credit Hours)
Course explores hands-on exposure to state-of-the-art algorithms in medical image analysis, which builds on open-source software (Insight Segmentation and Registration Toolkit - ITK), as well as the principles of medical image acquisition in the modalities of clinical interest. Medical imaging modalities - X-rays, CT, and MRI/ITK image pipeline; image enhancement, feature detection; segmentation - basic techniques, feature-based classification and clustering, graph cuts, active contour and surface models; surface and volume meshing; registration - transformations, similarity criteria; shape and appearance models are all explored and discussed in this course.

MSIM 872 Modeling Global Events (3 Credit Hours)
Modeling Global Events introduces modeling and simulation as a tool for expanding our understanding of events that have shaped the global environment of the 21st century. Students will review real-world case studies and then analyze these case studies via system dynamics, agent-based, social network, and game theory modeling paradigms. This course is designed to develop empirical research skills, conceptual modeling expertise, and model construction. Students will understand how to analyze, verify, and validate a model.

MSIM 874 Transportation Network Flow Models (3 Credit Hours)
This course provides a rigorous introduction to transportation network modeling, with special emphasis on network equilibrium problems. Topics include: elementary graph theory, shortest path problem nonlinear optimization, optimization of univariate functions, deterministic and stochastic user equilibrium. (Cross-listed with CEE 874).

MSIM 875 Transportation Network Algorithms (3 Credit Hours)
Fundamental models and algorithms in optimization, stochastic modeling and parallel computing will be discussed and illustrated with transportation applications. (Cross-listed with CEE 875)

MSIM 876 Simulation Modeling in Transportation Networks (3 Credit Hours)
Principles of simulation modeling, microscopic, mesoscopic, and macroscopic traffic simulation models. Course explores driver behavior in networks, calibration and validation of traffic simulation models, and use of traffic simulation software. (Cross-listed with CEE 876)

MSIM 880 Machine Learning II (3 Credit Hours)
Advanced topics in machine learning and pattern recognition systems. Data reduction techniques including principle component analysis, independent component analysis and manifold learning. Introduction to sparse coding and deep learning for data representation and feature extraction. (Cross-listed with ECE 880)
Prerequisites: MSIM 607 or equivalent

MSIM 892 Doctor of Engineering Project (1-9 Credit Hours)
Directed individual study applying advanced level technical knowledge to identify, formulate and solve a complex, novel problem in Modeling and Simulation.

MSIM 895 Topics in Modeling and Simulation (3 Credit Hours)
Special topics of interest with emphasis placed on recent developments in modeling and simulation.

MSIM 897 Independent Study in Modeling and Simulation (1-3 Credit Hours)
Individual study selected by the student. Supervised and approved by a faculty member with the approval of the graduate program director.
Prerequisites: permission of the instructor or graduate program director

MSIM 898 Research in Modeling and Simulation (1-12 Credit Hours)
Supervised research prior to passing Ph.D. candidacy exam.
Prerequisites: permission of the instructor and graduate program director

MSIM 899 Dissertation (1-12 Credit Hours)
Directed research for the doctoral dissertation.
Prerequisites: permission of the instructor and graduate program director

MSIM 998 Master's Graduate Credit (1 Credit Hour)
This course is a pass/fail course for master's students in their final semester. It may be taken to fulfill the registration requirement necessary for graduation. All master's students are required to be registered for at least one graduate credit hour in the semester of their graduation.

MSIM 999 Doctoral Graduate Credit (1 Credit Hour)
This course is a pass/fail course doctoral students may take to maintain active status after successfully passing the candidacy examination. All doctoral students are required to be registered for at least one graduate credit hour every semester until their graduation.

Centers and Institutes

The research laboratories and institutes directly associated with the department include:

- Applied Plasma Technology Laboratory (APTL)
- Bioelectrics and Pulsed Power
- Biomedical Devices and Biomanufacturing Lab
- CAVE Automated Virtual Environment (CAVE)
- Collaborative Autonomous Systems Laboratory
- Cybersecurity, Communications & Networking Innovation (CCNI) Laboratory
- Machine Intelligence and HF Communications Lab
- Medical Simulations Laboratory
- Plasma Engineering & Medicine Institute (PEMI)
- Systems Research Laboratory
- Virginia Institute for Photovoltaics (VIPV)
- Vision Lab
- Virginia Institute for Vision Analysis (VIVA)

In addition, the department has faculty with research labs at the Applied Research Center (ARC) at the Thomas Jefferson National Accelerator Facility. The ARC facilities include thin film fabrication equipment for applications in photovoltaics, thermoelectrics, superconductors, and semiconductors. ARC houses extensive materials analysis capabilities. These research facilities position the department for national leadership in several areas and as a leading research and higher education institution in the southeastern United States. In addition, the faculty have strong ties to the Thomas Jefferson National Accelerator Facility, Frank Reidy Center for Bioelectrics, the Center of Bioelectronics, and the Virginia Modeling, Analysis, and Simulation Center (VMASC).