

# COMPUTER ENGINEERING

- Master of Science in Computer Engineering

Guru Subramanyam, Department Chairperson

## Master of Science in Computer Engineering (CPE)

The program of study leading to the Master of Science in Computer Engineering (MSCPE) must include a minimum of 30 semester hours of credit consisting of the following:

ECE 500	Introduction to the Graduate Program in Electrical and Computer Engineering	0
ECE courses:		6
ECE 501	Contemporary Digital Systems	
ECE 532	Embedded Systems	
ECE 533	Computer Design	
CPS course:		3
CPS 510	System Analysis	
CPS 536	Operating Systems I	
CPS 570	Data Communications	
Concentration Area: <sup>1</sup>		9-12
Communications and Networking		
ECE 561	Digital Signal Processing	
ECE 537	Adv Engr Software	
CPS 572	Network Security	
Operating Systems & Computer Architecture		
ECE 536	Microprocessor Applications	
ECE 636	Advanced Computer Architecture	
CPS 544	Advanced UNIX/Linux Programming	
Software Engineering		
ECE 537	Adv Engr Software	
ECE 538	Object-Oriented Programming Applications	
CPS 512	System Design	
CPS 543	Advanced Concepts of Programming Languages	
CPS 542/562	Database Management Systems	
Embedded Systems		
ECE 531	Analog Integrated Circuit Design	
ECE 536	Microprocessor Applications	
Technical electives: <sup>2</sup>		6-9
Thesis Option: <sup>3</sup>		6
Academic Experience Option <sup>4</sup>		
Total Hours		30

<sup>1</sup> At least 12 semester hours are required in the concentration area for the non-thesis option.

<sup>2</sup> At least 9 semester hours of technical electives are required for the non-thesis option.

<sup>3</sup> Students receiving 50% assistantship/stipend over one academic year or more will be required to pursue the thesis option.

<sup>4</sup> Options for a successful completion of a:

1. Master's Thesis or
2. a non-thesis research of design project, including submission of a written report and a seminar presentation or
3. 6 approved credit hours requiring extensive project-based learning.

## Computer Science Courses

### CPS 501. Advanced Programming and Data Structures. 3 Hours

A bridge course for students who already have a programming background. Covers advanced data structures and programming techniques in a high level programming language.

### CPS 509. Topics in Computer Science. 1-3 Hours

Lectures in special areas of interest determined by the department. May be taken more than once for additional credit when the topics or contents change. Prerequisite(s): Permission of department chairperson.

### CPS 510. System Analysis. 3 Hours

Process-oriented, data-oriented, and object-oriented approaches for systems development; comparison of various systems development life cycles; DFD methodology for systems analysis using state-of-the-art CASE (Computer Aided Software Engineering) tools; logical and event analyses of DFD specifications; tools and techniques for modeling real-time systems; data modeling; introduction to object-oriented analysis methodologies. Prerequisite(s): CPS 350.

### CPS 512. System Design. 3 Hours

Principles of design, introduction to software design methodologies; issues in transition from analysis to logical and physical designs; detailed discussion of structured design methodology (Yourdon, Constantine, Myers); design guidelines; transform analysis; Warnier/Orr design methodologies; designing methodologies for real-time systems; introduction to object-oriented design; CASE tools and code generators. Prerequisite(s): CPS 510.

### CPS 518. Software Engineering. 3 Hours

No description available.

### CPS 520. Object-Oriented Systems Development. 3 Hours

Unified Modeling Language (UML), use cases, class diagrams, sequence diagrams, collaboration diagrams, state charts, activity diagrams, component and deployment views, design patterns, and implementation of various UML models through team projects. Prerequisite(s): CPS 350, 510.

### CPS 522. Software Project Management. 3 Hours

Cost and effort estimation models for software projects, planning techniques, productivity metrics, risk management, maintenance, reuse, quality assurance, configuration management, Capability Maturity Models (CMM and P-CMM), and ISO 9001. Prerequisite(s): CPS 510 or CPS 518 or CPS 520.

### CPS 530. Algorithm Design. 3 Hours

The design and analysis of computer algorithms, including order notation, sorting, dynamic programming, graph algorithms, string matching, matrix multiplication, NP-completeness. Prerequisite(s): CPS 350.

### CPS 534. Distributed Computing with Big Data. 3 Hours

This course introduces students to distributed computation frameworks (such as MapReduce) associated with massive datasets. Topics focus on parallel/distributed algorithms, data mining and machine learning algorithms for processing and analyzing very large amounts of data, and data visualization. Prerequisite(s): CPS 350.

**CPS 536. Operating Systems I. 3 Hours**

Models and algorithms pertinent to the design of computer operating systems; concurrent processes including synchronization, communication and deadlock problems, process and device scheduling policies, design of file systems, reliability and protection. Prerequisite(s): CPS 350.

**CPS 542. Database Management Systems. 3 Hours**

Physical and logical organization of data files; hierarchical, network, and relational database models; data definition language and data manipulation language of a commercial database management system; query languages. Prerequisite(s): CPS 350.

**CPS 543. Advanced Concepts of Programming Languages. 3 Hours**

This course involves the study of advanced programming language concepts and paradigms. Possible topics, covered at the discretion of the instructor, include metalinguistic abstraction and macros, fixed-point combinators, reflection and meta-object protocols, and generative and aspect-oriented programming with emphasis on applying these concepts in practical application domains. Prerequisite(s): CPS 352.

**CPS 544. Systems Programming. 3 Hours**

Analysis of compilers and their construction; programming techniques discussed in the current literature; advanced computer applications in both mathematical and nonnumeric areas. Prerequisite(s): CPS 350.

**CPS 552. Discrete Event Simulation Techniques. 3 Hours**

Simulation models; random number generation testing, special purpose simulation languages, statistical analysis of output; regenerative models; trace-driven models. Emphasis on models related to computer operating system design and performance evaluation. Prerequisite(s): CPS 350, statistics.

**CPS 560. Computer Graphics. 3 Hours**

Types of graphic hardware and their characteristics. Overview of software and techniques used in computer graphics. Two- and three-dimensional graphics displays. Students registering for this course should have programming ability in a procedure-oriented language. Prerequisite(s): CPS 350.

**CPS 561. Virtual Reality. 3 Hours**

This course offers a broad introduction of virtual reality from fundamental theories to software/hardware technologies involved with the current state of the art in VR. Topics include 3D interaction techniques on virtual immersive systems, human pose/face/hands tracking, graphics and 3D animation collaborative networked virtual environment, augmented reality systems, and security. Some unforeseen security issues in many emerging VR systems are also addressed. Prerequisite(s): CPS 350.

**CPS 562. Database Management Systems II. 3 Hours**

Study of query execution and optimization, transaction management, concurrency control, recovery and security techniques. Advanced data models and emerging trends in database systems, like object-oriented database systems, distributed database systems, client-server architecture, multidatabase and heterogeneous systems. Other current database topics and emerging technologies will be discussed. Prerequisite(s): CPS 542.

**CPS 563. Data Visualization. 3 Hours**

The study of methodologies to visualize different kinds of data such as big data or time series data. Main topics include principal component analysis, feature selection, clustering, parallel coordinates, and different kinds of visualization charts.

**CPS 564. Visual Computing and Mixed Reality. 3 Hours**

The study of methodologies to comprehend and create a mixed-reality application. Main topics focus on the components of visual computing and mixed-reality applications include image filtering, feature extraction, image matching, object tracking, and rendering.

**CPS 566. Image Processing. 3 Hours**

This course introduces students to a wide range of topics on digital image processing techniques. Topics includes image enhancement, 2D linear and nonlinear filtering, image compression and restoration, pattern recognition, big visual data analysis, and stochastic modeling on images. Prerequisite(s): CPS 350.

**CPS 567. Advanced Computer Vision. 3 Hours**

An introduction to computer vision including fundamentals of image formation, camera imaging geometry, feature detection and matching, and scene understanding. Students develop basic methods for applications that include finding known models in images, depth recovery from stereo, and pattern recognition.

**CPS 568. Advanced Interactive Media. 3 Hours**

A broad introduction to the concepts and common problems of digital data processing and the theoretical aspects of media and interactivity. This course uses a variety of principles and techniques to demonstrate the relationship between visual data sensing and interactivity fundamentals.

**CPS 570. Data Communications. 3 Hours**

The study of networks of interacting computers. The analysis of distributed processing and distributed databases. Prerequisite(s): CPS 350.

**CPS 572. Computer Networking. 3 Hours**

A unified view of the broad field of local area and long haul networks. A survey of the state of the art. Topics covered include networking theory, design approaches, standards, topologies and protocols. Prerequisite(s): CPS 536, CPS 570.

**CPS 573. Security and Safety in Autonomous Systems. 3 Hours**

Advanced autonomy has unique safety and security challenges due to continuous learning. This course explores methods for evaluating learning to ensure behavior(s) remain safe and secure. This course also explores advanced episodic and semantic memory structures and the ethics of autonomous systems.

**CPS 574. Language-Based Security. 3 Hours**

Language-based security course covers fundamental topics of programming language-based concepts for computer security. Application-level vulnerabilities and attacks are introduced and explored. This course covers the design and implementation of security mechanisms, and software security research in the area of programming languages and security. Together with lectures, students learn hands-on experience through practical labs, programming assignments, and a term project.

**CPS 575. Secure Application Development. 3 Hours**

An introduction to secure programming principles and practices to develop robust, secure software systems that are free from vulnerabilities. Constructive secure programming techniques are integrated with modern application development technologies so that security can be built in during the design phase of the development process to avoid potential software vulnerabilities and attacks. Prerequisite(s): CPS 501.

**CPS 576. Cyber Security Fundamentals. 3 Hours**

An examination of advanced topics in cybersecurity and application of those concepts to a modern networked operating system via course lectures and a project. Analytic methods for modeling fundamental cybersecurity structures are introduced.

**CPS 577. Computer System Design I. 3 Hours**

Introduction to design and analysis of combinational and sequential circuits of MSI devices to design arithmetic and other computer functions. Analysis of a specific microcomputer architecture including usage of its machine and assembler language. Interfacing of various components with computers. Prerequisite(s): CPS 250.

**CPS 579. Cyber Threats and Defense. 3 Hours**

This course provides foundational and advanced knowledge about the threats that may exist in cyberspace. Available defense techniques to mitigate threats within a system are also discussed. Prerequisite(s): CPS 470.

**CPS 580. Artificial Intelligence. 3 Hours**

Presentation of theoretical concepts for artificial intelligence in the areas of knowledge representation and search techniques. These are examined in the context of applications for expert systems, semantic networks, and planning problems. Issues concerning functional programming and logic programming are also presented. Prerequisite(s): CPS 350.

**CPS 581. Advanced Artificial Intelligence. 3 Hours**

This course continues the studies pursued in Artificial Intelligence CPS 580. It delves more deeply into certain areas such as multiple agent systems and induction, and introduces new areas, such as neural networks and planning, not covered in CPS 580. As in CPS 580, each student shall complete a final project investigating some area of research in Artificial Intelligence. The project will encompass a literature search, paper, presentation, and implementation.

**CPS 582. Automata Theory. 3 Hours**

Finite automata, sequential machines. Turing machines, computability, existence of self-reproducing machines. Prerequisite(s): CPS 528.

**CPS 583. Graph Algorithms. 3 Hours**

Design and analysis of algorithms for problems based on graphs. Classical algorithms and efficient algorithms for restricted domains of graphs are covered. Analysis of algorithms, complexity classes P, NP, and NP-complete, traversals, bi-connectedness, strongly-connectedness, 2-SAT, planarity testing, and algorithms for restricted classes of graphs. Prerequisite(s): CPS 501.

**CPS 584. Advanced Intelligent Systems and Deep Learning. 3 Hours**

Course goal focuses on building software on machines that behave "intelligently," enabling computer systems to "do the right thing" in complex environments so that they act optimally given limited information and computational resources available. Core topics of knowledge representation, reasoning, and learning are explored.

**CPS 591. Special Research Problems. 1-3 Hours**

Individual readings and research in a specialized area. May be taken for at most six semester hours. Prerequisite(s): Permission of department chairperson.

**CPS 592. Special Topics. 1-3 Hours**

Lectures and/or laboratory experience in some areas determined by the department. Prerequisite(s): Permission of department chairperson.

**CPS 595. Software Engineering Project I. 3 Hours**

First of a two-course project sequence. Students, either individually or in teams, must propose a project, conduct background research, justify the adequacy of the work for a graduate project, complete analysis and design using appropriate methodologies and CASE tools, and write preliminary coding. Students are expected to write code and minimize the usage of visual or other development environments. A minimum of three class presentations is expected for project proposal, progress, and final analysis/design. Prerequisite(s): (CPS 510, CPS 530); permission of department chairperson.

**CPS 596. Software Project II. 3 Hours**

Continuation of CPS 595. Students are required to implement the analysis and design of their projects and make periodic presentations. Special attention needs to be given to the overall architecture of the system, usability, testing, and documentation. A minimum of two class presentations is expected for design and implementation. Prerequisite(s): CPS 595.

**CPS 599. Thesis. 3-6 Hours**

Thesis.

**CPS 673. Advanced System Security Analysis. 3 Hours**

An examination of computer and network security using propositional and predicate logic and formal models. The course synthesizes elements from computer networking, operating systems security, and data security using access control matrices, protection models, confidentiality, integrity, representing identity, and information flow and confinement. Prerequisite(s): CPS 576.

**CPS 674. Current Topics in Autonomous Systems. 3 Hours**

A survey of current research articles and seminal papers in autonomy to determine the state-of-the-art in autonomous system capabilities. Prerequisite(s): CPS 573 and CPS 576.

**CPS 679. Research Methods, Performance Analysis, and Experimental Design. 3 Hours**

Presentation of techniques for the measurement, simulation, and analysis of computer systems, software, and communication networks. A systematic approach to performance evaluation is developed. This course introduces and applies advanced statistical methods and analysis techniques to ensure research conclusions are rigorous, defensible, and supported by the data collected.

**Electrical & Computer Engr Courses****ECE 500. Introduction to the Graduate Program in Electrical and Computer Engineering. 0 Hours**

Introduction to ECE graduate program, research methods in ECE, technical writing, literature research, ethics, software and resources.

**ECE 501. Contemporary Digital Systems. 3 Hours**

An introduction to modern digital hardware logic design using a hierarchical system approach including top-down development process. An introduction to alternative design implementation forms including hardware description languages (HDLs) for the design of simple and complex combinatorial logic circuits and sequential logic designs with finite state machines. Good HDL coding practices such as readability, re-configurability, and efficient execution are emphasized along with the use of programmable logic circuits including Field-Programmable Gate Arrays (FPGAs). Required Background: ECE215 or equivalent.

**ECE 503. Random Processes. 3 Hours**

Random variables as applied to system theory, communications, signal processing and controls. Topics include advanced engineering probability, random variables, random vectors and an introduction to random processes. Required background: ECE 340 or equivalent.

**ECE 505. Digital Signal Processing. 3 Hours**

A study of one-dimensional digital signal processing, including a review of continuous system analysis and sampling. Topics include z-transform techniques, digital filter design and analysis, and fast Fourier transform processing techniques. Required background: ECE 334 or equivalent course.

**ECE 506. Microelectronic Devices. 3 Hours**

Crystalline structure of matter, quantum mechanics and energy band theory; bulk properties of semiconductors; p-n and metal-semiconductor junctions; bipolar junction transistors; field-effect transistors; heterostructures; optical properties of semiconductors; devices, modeling and applications. Required background: ECE 304 or equivalent.

**ECE 507. Electromagnetic Fields I. 3 Hours**

Fundamental concepts, wave equation and its solutions; wave propagation, reflection and transmission; potential theory; construction of modal solutions; various electromagnetic theorems: concept of source, uniqueness, equivalence, induction and reciprocity theorems. Required background: ECE 333 or equivalent.

**ECE 509. Analysis of Linear Systems. 3 Hours**

State variable representation of linear systems and its relationship to the frequency domain representation using transfer functions and the Laplace transform. State transition matrix and solution of the state equation, stability, controllability, observability, state feedback and state observers are studied.

**ECE 510. Microwave Circuits for Communications. 3 Hours**

Microwave transmission, planar transmission lines, microwave components and filters. Microwave tubes, microwave communication, radar systems, and electronic support measures. Prerequisite(s): ECE 507.

**ECE 511. Antennas. 3 Hours**

Fundamental principles of antennas; analysis and synthesis of arrays; resonant antennas; broadband and frequency independent antennas; aperture and reflector antennas; applications to radar and communication systems. Prerequisite(s): ECE 507 or equivalent.

**ECE 521. Digital Communications I. 3 Hours**

Fundamentals of digital transmission of information over noisy channels; modulation schemes for binary and M-ary digital transmission; optimum receivers; coherent and noncoherent detection; signal design; intersymbol interference; error control coding; the Viterbi algorithm; channel capacity and Shannon limits on reliable transmission.

**ECE 523. Satellite Communications. 3 Hours**

Topics related to the theory, design and orbital placement of geostationary and geosynchronous satellites and their communications applications, including transmitters and receivers in the RF, microwave and optical operational windows, the associated modulation and communication strategies, system hardware and international satellite networks. Required background: ECE 507 or permission from instructor.

**ECE 530. Digital Integrated Circuit Design. 3 Hours**

Integrated circuit design and layout concepts, design methodology, fabrication process and limitations, MOSFET models for digital design, inverter and logic gates, interconnect and delay, combinational circuits, sequential circuits, datapath subsystems, memory circuits, digital phase lock loops. Required background ECE 304.

**ECE 531. Analog Integrated Circuit Design. 3 Hours**

Integrated circuit design concepts and layout; system perspective on analog design; MOS device theory and processing technology; current mirrors and biasing circuits; voltage and current references; single-stage, differential and operational amplifiers; CAD utilization to realize the design process. Required background: ECE 304 or equivalent.

**ECE 532. Embedded Systems. 3 Hours**

This course will introduce the student to the concept of embedded systems and the constraints imposed on hard real-time systems. Course will consist of design, development and test of selected hard-deadline hardware and software using Altera's DE2 development boards. The student will design selected hardware interfaces and develop real-time executive and application code in assembly language and C. Each student will design and implement hardware using Verilog HDL. Required Background: ECE 444 or equivalent.

**ECE 533. Computer Design. 3 Hours**

Design considerations of the computer; register transfer operations; hardware implementation of arithmetic processors and ALU; instruction set format and design and its effect on the internal microengine; hardware and micro-programmed control design; comparative architectures. Required background: ECE 314 or equivalent.

**ECE 536. Microprocessor Applications. 3 Hours**

Project studies, applications of microprocessors in practical implementations; logic implementation using software; memory mapped I/O problems and interrupt structure implementation; use of compilers; study of alternate microprocessor families including industrial controllers. Required background: ECE 314 or equivalent.

**ECE 538. Object-Oriented Programming Applications. 3 Hours**

A semi-formal approach to the engineering applications of object-oriented programming. Application of the concepts of classes, inheritance, polymorphism in engineering problems. Introduction to the use of class libraries. Effective integration of the concepts of application programmer interfaces, language features and class libraries. Required background is C programming experience.

**ECE 545. Automatic Control. 3 Hours**

Study of mathematical methods for control systems and analysis of performance characteristics and stability. Design topics include pole-placement, root locus, and frequency domain techniques. The student will also learn feedback loop sensitivity, basic loopshaping, performance bounds and other introductory aspects of robust control. Required background is ECE 415 or equivalent.

**ECE 547. Non-Linear Systems & Control. 3 Hours**

Introduction to nonlinear phenomena in dynamical systems. A study of the major techniques of nonlinear system analysis including phase plane analysis and Lyapunov stability theory. Application of the analytical techniques to control system design including feedback linearization, backstepping and sliding mode control. Prerequisite(s): ECE 509 or permission of instructor.

**ECE 563. Image Processing. 3 Hours**

An introduction to image processing including the human visual system, image formats, two-dimensional transforms, image restoration, and image reconstruction. Prerequisite(s): ECE 505.



**ECE 564. 3D Computer Vision. 3 Hours**

Develop the skills needed to generate synthetic images of 3D objects and to recover 3D structure from one or more views (projections) of 3D objects. Feature recognition in 2D views (images) of a scene based either on actual photographs or synthetic images (computer graphics generated). Applications in robot pose recognition and mobile robot navigation. Students should have experience with MATLAB programming and image processing.

**ECE 565. Fundamentals of Solid-State Batteries. 3 Hours**

Introduction to the fundamental of solid-state, safe, durable, batteries, including working principles of a battery, state-of-the-art battery (Li-ion battery based on liquid-state electrolytes- advantages/disadvantages), battery safety, need for a safe battery system for low-high power applications (electric vehicles / unmanned-/manned aircrafts, space vehicles, etc.), different design of solid-state batteries (planner-stacked, 3 dimensional, etc.), engineering the structural battery (dual functionality system that can carry mechanical load and store energy), characterization methods to evaluate structure / electrical / electrochemical properties of all solid-state battery materials (cathode, anode, electrolytes), interfaces (electrodes/electrolyte), and electrical/ electrochemical testing of complete battery cells. Also, electrical test methods to evaluate solid-state Li-ion battery (including structural battery) performances, etc.), and understanding degradation mechanism of solid-state battery systems (including structural battery) will be discussed. Required background: ECE 304 or equivalent.

**ECE 566. Fundamentals of Hybrid Electrochemical Power. 3 Hours**

Introduction to the fundamentals of hybrid electrochemical power (battery + capacitor + fuel cell – integrated systems) including working principles of batteries, capacitors, lithium-ion capacitors, and fuel cells. Discussion of the advantages/disadvantages, necessity to hybridize batteries, fuel cells, capacitors. Electrical hybridization methods, electrochemical testing of hybrid power systems, degradation mechanism, and applications. Hybrid electrochemical power is highly desirable to meet requirements for a wide range of products (such as electronic gadgets, transportation vehicles and space vehicles) requiring low to high power/energy, cycle-life, fast/slow charge/discharge, etc. Required background: ECE 304 or equivalent.

**ECE 567. Machine Learning & Patterning. 3 Hours**

This course introduces the fundamental concepts and models of machine learning with a practical treatment of design, analysis, implementation and applications of algorithms that learn from examples. Topics include supervised and unsupervised learning, self organization, pattern association, feed-forward and recurrent architectures, manifold learning, dimensionality reduction, and model selection. Required background in ECE445 or Graduate Student status.

**ECE 568. Detection and Estimation. 3 Hours**

This course will provide a fundamental understanding of detection, estimation, and their use in solving engineering problems. Students will be able to solve problems involving hypothesis testing, develop a discrete time signal detector, and compute optimum parameter estimates. Students will become familiar with foundational concepts of likelihood ratio, randomized decision, sufficient statistic, Cramer-Rao bounds, and risk estimation. Students will also develop understanding of linear least square estimation, minimum mean square estimation, minimum mean absolute error estimation, maximum a posteriori estimation, maximum likelihood estimation, minimum variance unbiased estimation, empirical Bayes estimation, and minimum risk shrinkage operator estimation, expectation-maximization algorithm. Prerequisite(s): ECE 503.

**ECE 569. Advanced Random Processes. 3 Hours**

This course will provide students with a fundamental understanding of probability, random variables and random processes, and their use in solving engineering problems. Students will be able to solve problems involving various noise processes and their probability distributions, describe random signals, and will analyze linear systems with stochastic inputs. Some advanced topics such as Wiener filtering, Kalman filtering, and Karhunen-Loeve decomposition will be covered. Prerequisite(s): ECE 503.

**ECE 572. Optical Information Processing. 3 Hours**

Mathematical techniques pertaining to linear systems theory; Fresnel and Fraunhofer diffraction; Fourier transform properties of lenses; frequency analysis of optical systems, spatial filtering, applications such as optical information processing and holography.

**ECE 573. Photonic Devices & Systems. 3 Hours**

Solid-state theory of optoelectronic devices; semiconductor photoemitters; LED's, optical amplifiers and semiconductor lasers; photodetectors: PIN, APD, photocells, PMT, detection and noise; solar cells; cameras and displays; electro-optic and magneto-optic devices; integration and application of electro-optical components in systems of various types. Prerequisite(s): ECE 507 or permission of department chairperson.

**ECE 574. Guided Wave Optics. 3 Hours**

Light propagation in slab and cylindrical waveguides; signal degradation in optical fibers; optical sources, detectors, and receivers; coupling; transmission link analysis; fiber fabrication; fiber sensor and communication systems. Prerequisite(s): ECE 507 or permission of department chairperson.

**ECE 576. Introduction to Radar. 3 Hours**

Introduction to the radar range equation, fields and Waves, antennas and phased arrays, beamforming, targets and clutter radar cross section, fast time, slow time, detection processing, tracking, space-time adaptive processing, FMCW radar, SAR and ISAR, electronic warfare, transmitters, receivers and signal processors. Required background: ECE303, ECE332, ECE340, or equivalent.

**ECE 577. Introduction to Electronic Warfare (EW). 3 Hours**

Overview of the Principles of Electronic Warfare (EW). Review of radar (and radio frequency communication) systems engineering, including fields and waves, waveforms, antennas and array beamforming, targets detection and image processing, tracking, space-time adaptive processing (STAP), synthetic aperture radar (SAR), Inverse SAR (ISAR). Principles of direction finding (DF), Electronic Attack (EA) of MTI (moving target indication) radar, SAR, and digital radio frequency memory (DRFM). Principles of Electronic Protection (EP) in MTI and SAR. Low Probability of Intercept (LPI) radar and communications, Electronic Intelligence and STAP, Electronic Support Measures (ESM). Required Background: ECE303, ECE332, ECE340, or equivalent. Recommended: ECE576.

**ECE 578. Advanced Radar. 3 Hours**

Review of the radar range equation, fields and waves, antennas and phased arrays, beamforming, targets and clutter radar cross section, fast time, slow time, detection processing, tracking, frequency modulated continuous wave (FMCW) radar, synthetic aperture radar (SAR) and Inverse SAR (ISAR), electronic warfare (EW), transmitters, receivers and signal processors. Advanced space-time adaptive processing (STAP) techniques, including the Generalized Likelihood Ratio Test, Non-Homogeneity Detection, Knowledge-Based STAP, and Constant False Alarm Rate detection processing. Required Background: ECE303, ECE332, ECE340, ECE512 or equivalent. Recommended: ECE515.

**ECE 580. Principles of Nanofabrication. 3 Hours**

Basic principles of processes used in microelectronic and photonic device fabrication: vacuum systems, plasma processes, physical and chemical vapor deposition, properties of silicon and other substrate materials, photolithography and non-optical lithography, wet chemical and plasma etching, thermal oxidation of silicon, semiconductor doping, ion implantation, metallization, electrical contacts and micro-metrology.

**ECE 581. Nanoelectronics. 3 Hours**

Introduction to the physics of materials on the nanoscale; quantum confinement theory; electronic and optical properties of semiconductor nanostructures; single electron transistors (SETs); tunneling and ballistic devices; nanostructured LEDs, photodetectors, and lasers; nanophotovoltaics and nanomagnetism; quantum computing and molecular electronics; nanoelectronic fabrication, state-of-the-art and emerging nanoscale devices and applications. Prerequisite(s): ECE 506 or permission of instructor.

**ECE 583. Advanced Photovoltaics. 3 Hours**

Science and applications of photovoltaics, with special emphasis on inorganic and organic semiconductors, ferroelectrics, chalcopyrites, metamaterials, quantum structures and photovoltaics architecture. Prerequisite(s): ECE 506 or permission of instructor.

**ECE 586. Computer Networks. 3 Hours**

Introduction to the fundamental of computer networks, including the Open Systems Interconnection reference model, transmission media, medium access protocol, data link protocols, routing, congestion control, applications, and network security. Recommended prerequisite: ECE 303.

**ECE 587. Wireless Security. 3 Hours**

Wireless security is a very important topic and attracting more and more attention from industry, research, and academia. This course gives a comprehensive overview on the recent advances in wireless network and system security. It will cover security issues and solutions in emerging wireless access networks and systems as well as multi-hop wireless networks. Required background: ECE203 or equivalent.

**ECE 595. Special Problems in Electrical Engineering. 1-6 Hours**

Particular assignments to be arranged and approved by the department chair.

**ECE 599. Thesis. 1-6 Hours**

Thesis in Electrical and Computer Engineering.

**ECE 633. Advanced Computer Architecture. 3 Hours**

Examination of modern high performance computing architectures, including out-of-order execution RISC multicore processors and GPGPUs. Design projects integrate the concepts learned in class. Prerequisite(s): ECE 533.

**ECE 642. Optimal Control & Estimation. 3 Hours**

Introduction to optimal control, starting with dynamic programming for stochastic optimal control; continuous time optimal control, including Pontryagin's Maximum Principle and its application to the linear case, leading to linear optimal control. Prerequisite(s): ECE 509 or permission of instructor.

**ECE 645. Adaptive Control. 3 Hours**

On-line approximation based adaptive control techniques for nonlinear systems. An introduction to neural networks and fuzzy systems as part of the control loop is given, leading to a diversity of advanced methods for controlling and stabilizing nonlinear systems subject to uncertainties. Adaptive observers and adaptive output feedback are also introduced. Prerequisite(s): ECE 547 or permission of instructor.

**ECE 661. Statistical Signal Processing. 3 Hours**

This course studies discrete methods of linear estimation theory. Topics include random vectors, linear transformations, linear estimation theory, optimal filtering, least squares techniques, linear prediction, and spectrum estimation. Prerequisite(s): ECE 503, ECE 505.

**ECE 682. Nano-Fabrication Laboratory. 3 Hours**

This laboratory course will provide hands-on experience in state-of-the-art device fabrication technology. The course will be conducted primarily in a clean room laboratory with some classroom sessions for discussions. The students will have an opportunity to design, fabricate and test their own devices. Prerequisite(s): Permission of instructor.

**ECE 695. Special Problems in Electrical and Computer Engineering. 1-6 Hours**

Special topics in electrical engineering not covered in regular courses. Course sections arranged and approved by the chair of the student's doctoral advisory committee and the department chair.

**ECE 696. Graduate Seminar. 0-3 Hours**

Research oriented independent study course intended for doctoral level graduate students. The student will perform an in-depth research on a selected topic of mutual interest with his/her doctoral adviser, and achieve sufficient expertise to do a technical presentation about the topic in front of his/her peers. The student will prepare a report and present it in one of the graduate seminar sessions during the semester. The student is expected to attend all the seminars presented by other graduate students during the semester and to interact with them to improve the depth and breath of his/her knowledge.

**ECE 699. PhD Dissertation. 1-15 Hours**

Original research in electrical engineering that makes a definite contribution to technical knowledge. Results must be of sufficient importance to merit publication in a refereed journal.