DEPARTMENT OF COMPUTER SCIENCE ELECTRICAL ENGINEERING

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Department Description
Undergraduate Degrees:
• Bachelor of Information Technology (http://catalog.umkc.edu/colleges-schools/computing-engineering-school-of/computer-science-electrical-engineering/bachelor-of-information-technology/)
• Bachelor of Science in Computer Science (http://catalog.umkc.edu/colleges-schools/computing-engineering-school-of/computer-science-electrical-engineering/computer-science-bs/)
A BS/MS Option for completing both an undergraduate degree and a masters degree within five years is available for CS and ECE/EE. Furthermore, a minor in computer science is available as well.

The two degrees in computer science are the bachelor of arts in computer science (B.A. with a liberal arts perspective), and bachelor of science in computer science (B.S. with a more thorough technical perspective). The bachelor of science in electrical and computer engineering (B.S.) is for students wanting to pursue a career in electrical engineering or electrical and computer engineering. The bachelor of information technology (B.I.T.) degree caters to the needs of the IT industry and uniquely blends both computer science and business coursework.

Graduate Degrees:

- Master of Science in Computer Science
- Master of Science in Electrical Engineering
- Doctoral Studies in Computer Science or Electrical Engineering

Computer Science Courses

COMP-SCI 100 Computer Fundamentals and Applications
Credits: 3
The course covers essential computer concepts and skills. The emphasis is on using the computer as a tool to enhance productivity. Topics include basic computer concepts such as what to look for when buying a computer and how to avoid hackers and viruses when operating one. Students will also learn how to create word processing, spreadsheet, database, and presentation documents using the Microsoft Office suite of applications. The course prepares students to succeed in both college and business by enabling them to write reports, analyze and chart data, prepare presentations and organize large data sets.

Prerequisites: MATH 110 (or higher) or ALEKS score of 51 (or higher); or ACT Math sub-score of 28 or higher; or SAT Math sub-score of 660 or higher.

COMP-SCI 101 Problem Solving and Programming I
Credits: 3
Problem solving, algorithms, and program design. Use of structured programming, lists, control structures, recursion, objects and files in Python. Introduction to graphical interface programming. Coding, testing and debugging using a modern development environment.

Prerequisites: MATH 110 or MATH 120 (or higher) or ALEKS score of 51 (or higher); ACT Math sub-score of 28 or higher; or SAT Math sub-score of 660 or higher.

Co-requisites: COMP-SCI 101L.

COMP-SCI 101L Problem Solving & Programming I Lab
Credit: 1
Programming exercises and demonstrations to reinforce concepts learned in COMP-SCI 101 and provide additional practice in Python programming.

Prerequisites: MATH 110 or MATH 120 (or higher); ACT Math sub-score of 28 or higher; or SAT Math sub-score of 660 or higher.


COMP-SCI 191 Discrete Structures I
Credits: 3
Mathematical logic, sets, relations, functions, mathematical induction, algebraic structures with emphasis on computing applications.

Prerequisites: MATH 110 or MATH 120 (or higher) or ALEKS score of 51 (or higher); or ACT Math sub-score of 28 or higher; or SAT Math sub-score of 660 or higher.

COMP-SCI 201L Problem Solving and Programming II - Lab
Credit: 1
Programming exercises and demonstrations to reinforce concepts learned in COMP-SCI 201R and provide additional practice in C++ programming.

Prerequisites: COMP-SCI 101.

Co-requisites: COMP-SCI 191 and COMP-SCI 201R.

COMP-SCI 201R Problem Solving and Programming II
Credits: 3
Problem solving and programming using classes and objects. Algorithm efficiency, abstract data types, searching and sorting, templates, pointers, linked lists, stacks and queues implemented in C++.

Prerequisites: COMP-SCI 101.

Co-requisites: COMP-SCI 191 and COMP-SCI 201L.
COMP-SCI 281R Introduction to Computer Architecture and Organization Credits: 3
Digital Logic and Data Representation, process architecture and instruction sequencing, memory hierarchy and bus-interfaces and functional
organization.
Prerequisites: COMP-SCI 101, COMP-SCI 191.

COMP-SCI 291 Discrete Structures II Credits: 3
Recurrence relations and their use in the analysis of algorithms. Graphs, trees, and network flow models. Introduction to Finite state machines,
grahams, and automata.
Prerequisites: COMP-SCI 191.

COMP-SCI 303 Data Structures Credits: 3
Linear and hierarchical data structures, including stacks, queues, lists, trees, priority queues, advanced tree structures, hashing tables, dictionaries and
disjoint-set. Abstractions and strategies for efficient implementations will be discussed. Linear and hierarchical algorithms will be studied as well as
recursion and various searching and sorting algorithms. Programming concepts include Object Orientation, concurrency and parallel programming.
Several in-depth projects in C++ will be required.
Prerequisites: COMP-SCI 191, COMP-SCI 201R, and COMP-SCI 201L.

COMP-SCI 304W Ethics and Professionalism Credits: 3
Societal and ethical obligations of computer science, information technology, and electrical/computer engineering practice. Topics include obligations
of professional practice, electronic privacy, intellectual property, ethical issues in networking, computer security, computer reliability, and whistle-
blowing.
Prerequisites: Departmental consent.

COMP-SCI 320 Data Communications and Networking Credits: 3
This course examines the fundamental aspects of data communications and computer networks. Students will learn the concepts of layered models,
communication protocols, digital transmission and encoding techniques, multiplexing techniques, error detection and correction concepts, the data
link layer and its associated protocols, LAN architectures, switching techniques, major Internet protocols and standards, internetworking, addressing,
and routing concepts. By the end of the course, students will be familiar with all networking concepts and technologies and will be able to size and
implement different types of networking architectures. Part of the course will be devoted to the use of opensource software tools, such as Cisco
Packet Tracer and Wireshark, to experiment with network architectures and analyze network traffic. Prerequisites: COMP-SCI 291.

COMP-SCI 371 Database Design, Implementation and Validation Credits: 3
This course discusses in detail all aspects of database management systems. It covers in detail database design, implementation, and validation.
In addition to these, it briefly covers implementation, tuning, database security, and implementation. The course is suitable for undergraduates and
professionals alike.
Prerequisites: COMP-SCI 303.

COMP-SCI 394R Applied Probability Credits: 3
Basic concepts of probability theory. Counting and measuring. Probability, conditional probability and independence. Discrete, continuous, joint
random variables. Functions of random variables. Sums of independent random variables and transform methods. Random number generation
and random event generation. Law of large numbers, central limit theorem, inequalities. Their applications to computer science and electrical and
computer engineering areas are stressed.
Prerequisites: COMP-SCI 201R and COMP-SCI 201L (or E&C-ENGR 216), MATH 220, and STAT 235 (or E&C-ENGR 241, or STAT 115, or MOTRMATH
110).

COMP-SCI 404 Introduction to Algorithms and Complexity Credits: 3
A rigorous review of asymptotic analysis techniques and algorithms: from design strategy (such as greedy, divide-and-conquer, and dynamic
programming) to problem areas (such as searching, sorting, shortest path, spanning trees, transitive closures, and other graph algorithms, string
algorithms) arriving at classical algorithms with supporting data structures for efficient implementation. Throughout, the asymptotic complexity is
studied in worst case, best case, and average case for time and/or space, using appropriate analysis techniques (recurrence relations, amortization).
Introduction to the basic concepts of complexity theory and NP-complete theory.
Prerequisites: COMP-SCI 291 and COMP-SCI 303.

COMP-SCI 420 Advanced Networking and Applications Credits: 3
This course provides advanced knowledge in computer networking and applications. More specifically, the students will learn new networking
concepts, such as software-defined networking (SDN), next-generation networking protocols, such as IPv6, how streaming of multimedia flows and
group communications are performed in the Internet, how networks are managed through remote network management platforms, and how to secure
networking architectures.
Prerequisites: COMP-SCI 320.

COMP-SCI 421A Foundations of Data Networks Credits: 3
This introductory course examines the analytical aspects of data communications and computer networking. Topics cover protocol concepts and
performance analysis that arise in physical, data link layer, MAC sub layer, and network layer.
Prerequisites: COMP-SCI 291, COMP-SCI 303, COMP-SCI 394R.
COMP-SCI 423 Client/Server Programming and Applications Credits: 3
Fundamentals of Client/Server programming using socket interface; features of network programming including connection oriented and connectionless communication in multiple environments (Windows, UNIX, and Java); other client/server mechanisms, such as RPC and RMI) and formal object environments designed to facilitate network programming (CORBA, COM and Beans).
Prerequisites: COMP-SCI 303, COMP-SCI 431.

COMP-SCI 424 Software Methods and Tools Credits: 3
This course covers a number of software methods and tools that are widely used in industry. These methods include architecture patterns and styles, software frameworks, unit testing, and version control. The covered software tools include Microsoft Project, IBM Rational Systems Modeler, Eclipse Plug-ins, JUnit, Subversion, and GIT. The course emphasizes practice. Students will use these methods and tools to develop a software system from the initial planning to final deployment.

COMP-SCI 431 Introduction to Operating Systems Credits: 3
This course covers concurrency and control of asynchronous processes, deadlocks, memory management, processor and disk scheduling, x86 assembly language, parallel processing, security, protection, and file system organization in operating systems.
Prerequisites: COMP-SCI 303, COMP-SCI 281R.

COMP-SCI 441 Programming Languages: Design and Implementation Credits: 3
This course covers programming language paradigms (object-oriented programming, functional programming, declarative programming, and scripting) and design tradeoffs in terms of binding, visibility, scope, lifetime, type-checking, concurrency/parallelism, and abstraction. It also covers programming language specification, grammar, lexical analysis, exception handling, and runtime considerations.
Prerequisites: COMP-SCI 303.

COMP-SCI 449 Foundations of Software Engineering Credits: 3
The course introduces concepts of software engineering (e.g. definitions, context) and the software development process (i.e. life cycle). Students will get a solid foundation in agile methodology, software requirements, exceptions and assertions, verification and validation, software models and modeling, and user Interface design. Various software architectures will be discussed.
Prerequisites: COMP-SCI 303.

COMP-SCI 451R Software Engineering Capstone Credits: 3
The course will focus on the requirements and project planning and managing of medium sized projects with deliverables of each phase of the software life cycle. Additional studies of system integration and architecture, software modeling, requirements specifications, configuration management, verification, validation, software evolution and quality and finally measurement, estimation and economics of the software process.
Prerequisites: COMP-SCI 303, COMP-SCI 449.

COMP-SCI 456 Human Computer Interface Credits: 3
Design of human-computer interfaces considering the psychological and physical abilities of the user. User interface design from a functional and ergonomic perspective. Contents organization, visual organization, navigation. Use of graphical user interface (GUI) and the development of high quality user interfaces.
Prerequisites: COMP-SCI 449.

COMP-SCI 457 Software Architecture: Requirements & Design Credits: 3
Introduction to requirements and design engineering with emphasis on organization and presentation of system requirements and designs for customers, users and engineers; validation of requirements and design with needs of system customer; examination of requirement and design changes during the lifetime of a system; transformation of informal ideas into formal detailed descriptions; examination of the different stages in the design process including architectural design, interface design and data structure design, database design, program and transaction design; examination of domain modeling criteria and examination of design quality attributes; non-functional attributes and project resource allocation.
Prerequisites: COMP-SCI 303.

COMP-SCI 458 Software Testing and Verification Credits: 3
Introduction to principles and techniques of software testing and verification for quality assurance in software development processes.
Prerequisites: COMP-SCI 303.

COMP-SCI 461 Introduction to Artificial Intelligence Credits: 3
This course provides an overview of the field of artificial intelligence. Topics include guided and unguided search, adversarial search, generation and use of heuristics, logic programming, probabilistic reasoning, and neural networks. Application areas studied include game playing, automated proofs, expert systems, and data mining. Recommended preparation: One or more of COMP-SCI 394R, COMP-SCI 404, or an advanced programming elective.
Prerequisites: COMP-SCI 303.
COMP-SCI 465R Introduction to Statistical Learning Credits: 3
This course provides a practical introduction to analytical techniques used in data science and prepares students for advanced courses in machine learning. Topics covered include multivariate distributions, information theory, linear algebra (eigenanalysis), supervised/unsupervised learning, classification/regression, linear/non-linear learning, introduction to Bayesian learning (Bayes rule, prior, posterior, likelihood), parametric/non-parametric estimation.
Prerequisites: COMP-SCI 394R.

COMP-SCI 470 Introduction to Database Management Systems Credits: 3
This course covers database architecture, data independence, schema, Entity-Relationship (ER) and relational database modeling, relational algebra and calculus, SQL, file organization, relational database design, physical database organization, query processing and optimization, transaction structure and execution, concurrency control mechanisms, database recovery, and database security.
Prerequisites: COMP-SCI 303.
Co-requisites: COMP-SCI 431.

COMP-SCI 479 Introduction to Computer Vision Credits: 3
Image is an essential form of information representation and communication in modern society. This course focuses on topics of computer vision, teaching computers how to understand images. Introductory topics include image formation, color and texture features, homograph, key points detection, aggregation, subspace methods in image modeling, and deep learning based image segmentation and classification, with applications in photography, media and entertainment, education, defense and medicine. The course is project based and emphasis hands on experiences for students to solve real world problems.
Prerequisites: E&C-ENGR 484.

COMP-SCI 490 Special Topics Credits: 3
Selected topics in specific areas of computer science. May be repeated for credit when the topic varies.
Prerequisites: Junior standing.

COMP-SCI 490CR Special Topics Credits: 1-3
Special topics in Computer Science.

COMP-SCI 490R Special Topics Credits: 1-3
Selected topics in specific areas of computer science. May be repeated for credit when the topic varies.

COMP-SCI 491 Internship Credits: 0-6
Students may participate in structured internships under the joint supervision of an employer and a faculty member. The student must carry out significant professional responsibilities that also have academic merit. The number of credit hours is based on the quality of the academic experience. Available for credit/no credit only and students must be in good standing with at least 18 credit hours of CS/IT counting towards the degree. Registration by consent number only. Petition forms for CS/IT 491 Internships are available in the office of CSEE Division and on the web.
Prerequisites: Junior standing, Departmental consent.

COMP-SCI 497 Directed Readings Credits: 1-3
Readings in an area selected by an undergraduate student in consultation with a faculty member. Arrangements must be made prior to registration.
Prerequisites: Departmental consent.

COMP-SCI 498 Research Seminar Credits: 1-3
Undergraduate research based on intensive readings from the current research literature under the direction of a faculty member. Arrangements must be made prior to registration.
Prerequisites: Departmental consent.

COMP-SCI 499 Undergraduate Research Credits: 1-3
Completion of project, including a final written report, under the direction of a faculty member. A prospectus must be accepted prior to registration.
Prerequisites: Departmental consent.

COMP-SCI 5101 Discrete Structures Review for Graduate Students Credits: 1-3
A review of mathematical logic, sets, relations, functions, mathematical induction, and algebraic structures with emphasis on computing applications. Recurrence relations and their use in the analysis of algorithms. Graphs, trees, and network flow models. Introduction to finite state machines, grammars, and automata. Students must have completed College Algebra before taking this course.

COMP-SCI 5102 Operating Systems Review for Graduate Students Credits: 1-3
This course covers concurrency and control of asynchronous processes, deadlocks, memory management, processor and disk scheduling, parallel processing, and file system organization in operating systems.
Prerequisites: Data Structures, Computer Architecture.
COMP-SCI 5103 Advanced Data Structures and Analysis of Algorithms Review for Graduate Students Credits: 1-3
A review of linear and hierarchical data structures, including stacks, queues, lists, trees, priority queues, advanced tree structures, hashing tables, dictionaries and disjoint-sets. Asymptotic analysis techniques and algorithms: from design strategy (such as greedy, divide-and-conquer, and dynamic programming) to problem areas (such as searching, sorting, shortest path, spanning trees, transitive closures, graph algorithms, and string algorithms) arriving at classical algorithms with efficient implementation. Introduction to the basic concepts of complexity theory and NP-complete theory. Students must have taken courses in Linear Algebra, Discrete Structures, Data Structures, and Applied Probability before taking this course.

COMP-SCI 514 Optical Fiber Communications Credits: 3
Fiber optic cable and its characteristics, optical sources and transmitters, optical detectors and receivers, optical components such as couplers and connectors, WDM and OFDM techniques, modulation and transmission of information over optical fibers, design of optical networks, single and multihop fiber LANs, optical carrier systems.
Prerequisites: COMP-SCI 411.

COMP-SCI 552 Cloud Computing Credits: 3
Cloud computing systems operate in a very large scale, and are impacting the economics and the assumptions behind computing significantly. This special topics course provides a comprehensive overview of the key technical concepts and issues behind cloud computing systems such as compute, storage and network resource virtualization and management. We will cover a range of topics of cloud computing including: Cloud system architectures and taxonomy, Computing virtualization techniques, Virtual machine resource management, Data center networking issues, Big data transfer protocols and management, Large scale distributed file system examples (Google File System), Cloud programming.
Prerequisites: CSEE 5110, COMP-SCI 431.

COMP-SCI 5531 Advanced Operating Systems Credits: 3
Components of an operating system, scheduling/routing mechanisms, process control blocks, design and test various operating system components.
Prerequisites: COMP-SCI 431.

COMP-SCI 5540 Principles of Big Data Management Credits: 3
This course will introduce the essential characteristics of Big Data and why it demands rethinking how we store, process, and manage massive amounts of structured and unstructured data. It will cover the core technical challenges in Big Data management i.e., the storage, retrieval, and analysis of Big Data. It will emphasize on fundamental concepts, analytical skills, critical thinking, and software skills necessary for solving real-world Big Data problems. Tools such as Apache Hadoop, Pig, Hive, HBase, and Apache Spark will be covered. Extensive reading of research papers and in-class presentations will be heavily emphasized in this class.
Prerequisites: COMP-SCI 431 and COMP-SCI 470.

COMP-SCI 5542 Big Data Analytics and Applications Credits: 3
Big Data analytics focus on analyzing large amounts of data to find useful information and to make use of the information for better business decisions. This course introduces students to the practice and potential of big data analytics and applications. In this course, students will have hands-on experience with Big Data technologies (Hadoop and its ecosystems) and tools (Cloudera, RMahout, HBase) for the analysis of large data sets across clustered systems. Students will learn how to develop highly interactive applications for business intelligence.
Prerequisites: COMP-SCI 451.

COMP-SCI 5543 Real-time Big Data Analytics Credits: 3
This course teaches students fundamental theory and practice in the field of big data analytics and real time distributed systems for real time big data applications. In this course, students will have hands-on experience for the development of real-time applications with various tools such as Twitter's Storm, Apache Flume, Apache Kafka for real time analysis of stream data such as twitter messages and Instagram images.
Prerequisites: COMP-SCI 451.

COMP-SCI 5551 Advanced Software Engineering Credits: 3
Current concepts in software architecture and design, comparative analysis for design, object-oriented software design, software quality criteria for evaluation of software design. Introduction to metrics, project management and managerial ethics.
Prerequisites: COMP-SCI 451R.

COMP-SCI 5552A Formal Software Specification Credits: 3
Formal modeling including specification and deviation of abstract data types, completeness issues in the design of data types and data structures, implementation of data structures from a formal data type specification, verification of abstract to concrete data mapping.
Prerequisites: COMP-SCI 291, COMP-SCI 303.

COMP-SCI 5553 Software Architecture and Design Credits: 3
The course introduces a number of basic concepts and enabling technologies of software architecture, including architecture styles, architecture description languages, architecture-implementation mapping, and product line architectures. It also covers some advanced topics, such as the REST architecture style and Web Services. Students will read research papers, analyze the existing results, write critiques, give presentations, and exercise the research results with real examples. In addition, students will have an opportunity to work in groups and study the architecture of some real software systems.
Prerequisites: COMP-SCI 451R.
COMP-SCI 5555 Software Methods and Tools Credits: 3
Software methods and tools are extensively used in current software production to improve software productivity and quality. In this course, we are going to learn a number of popular software methods and tools being used in industry. These methods include object-oriented design and analysis (e.g. UML, design patterns), architecture styles, code generation, and unit testing. The covered software tools include Microsoft Project, IBM Rational Systems Developer, Eclipse Plug-ins, Emacs, JUnit, Subversion, and GIT. The course emphasizes practice, and students will be using these methods and tools to develop a software system, from the initial planning to the final deployment.

COMP-SCI 5560 Knowledge Discovery and Management Credits: 3
This course teaches students fundamental theory and practice in the field of knowledge discovery and management and also provides them with hands-on experience through application development.

Prerequisites: COMP-SCI 5551, COMP-SCI 461.

COMP-SCI 5561 Advanced Artificial Intelligence Credits: 3
AI systems and their languages, implementations and applications, case studies of various expert systems, current research topics in AI, logic programming using PROLOG.

Prerequisites: COMP-SCI 461.

COMP-SCI 5565 Introduction to Statistical Learning Credits: 3
Introduction to Machine Learning; Multivariate Distributions; Information Theory; Linear Algebra (Eigenanalysis); Supervised/Unsupervised Learning, Classification/Regression; Linear/Non-linear Learning; Introduction to Bayesian Learning (Bayes rule, Prior, Posterior, Maximum Likelihood);Parametric/Non-parametric Estimation. Recommended preparation: MATH 300; Familiarity with MATLAB.

Prerequisites: COMP-SCI 394R.

COMP-SCI 5566 Introduction to Bioinformatics Credits: 3
This course introduces students to the field of Bioinformatics with a focus on understanding the motivation and computer science behind existing Bioinformatic resources, as well as learning the skills to design and implement new ideas.

Prerequisites: COMP-SCI 303, a course or background in Biology (Genomics or Meta Models preferred).

COMP-SCI 5567 Machine Learning for Data Scientists Credits: 3
This course teaches the theoretical basis of methods for learning from data, illustrated by examples of applications to several domains. Recommended preparation: COMP-SCI 5565.

Prerequisites: COMP-SCI 303, COMP-SCI 394R.

COMP-SCI 5568 Fundamentals of Probabilistic Graphical Models Credits: 3
Many real world systems are probabilistic in nature. Probability theory gives us the basic tools for modeling many real world systems, allowing us to understand complex behavior. Probabilistic graphical models allow us to model complex probabilistic relationships using graphs. This framework, which spans methods such as Bayesian networks and Markov networks, allows us to manipulate complex probability distributions that often involve hundreds or even many thousands of variables. These methods have been used for an enormous range of applications, which include: web search, turbo coding, robot navigation, image identification, epidemic identification in complex networks, medical diagnosis and speech recognition. Recommended preparation: COMP-SCI 5565.

Prerequisites: COMP-SCI 303, COMP-SCI 394R.

COMP-SCI 5570 Architecture of Database Management Systems Credits: 3
Covers in detail, architecture of centralized database systems, database processing, management of concurrent transactions, query processing, query optimization, data models, database recovery, data warehousing, workflow, World Wide Web and Database performance, and reviews the architecture of some commercial centralized database systems.

Prerequisites: COMP-SCI 431, COMP-SCI 470.

COMP-SCI 5572 Mobile Computing Credits: 3
This course covers in detail the architecture of mobile and wireless network. It discusses and develops reveland concepts and algorithms for building mobile database systems (MDS), which is necessary for managing information on the air and E-commerce.

Prerequisites: COMP-SCI 5570.

COMP-SCI 5573 Information Security and Assurance Credits: 3
This course deals with information security and assurance and covers the concepts necessary to secure the cyberspace. It introduces security models, assurance policies, security policies and procedures, and technology. It enables students to understand the need for information assurance, identify security vulnerabilities, and devise security solutions that meaningfully raise the level of confidence in computer systems. It teaches students how to design secured database and computer systems.

Prerequisites: COMP-SCI 470.
COMP-SCI 5574 Large Scale Semistructured Data Management Credits: 3
This course will cover topics related to managing large scale semistructured data modeled using the Extensible Markup Language XML and the Resource Description Framework (RDF). This will include storing XML (e.g. natively, using a relational database), indexing XML (e.g. numbering schemes, structural indexes, sequencing paradigms), XML query processing algorithms (e.g. join-based, subsequence-based), RDF DATA STORAGE (e.g. triple stores, graph stores), RDF indexing and SPARQL query processing algorithms. The course will also cover emerging many core processor architectures (e.g. Intel Single-chip Cloud Computer) and the opportunities they provide for building next-generation semistructured data management solutions. Extensive reading of research papers and in-class presentations will be a core part of this class. Grades will be based on in-class presentations of research papers, exams, and a research project (to be done in groups).

Prerequisites: COMP-SCI 470.

COMP-SCI 5581 Parallel Computer Architecture I Credits: 3
Parallelism in computer architecture, pipelined processors, array processors and multi-processor systems, algorithms for SISD, SIMD, MISD and MIMD organizations, vectorization, pipelining algorithms.

COMP-SCI 5582 Computer Vision Credits: 3
The image is an essential form of information representation and communication in modern society. This course focuses on topics of computer vision, teaching computer how to understand images. Topics include image formation, color and texture features, key points detection, aggregation, subspace methods in image modeling, and deep learning image classification, with many applications in photography, media and entertainment, education, defense and medicine.

COMP-SCI 5590 Special Topics Credits: 1-6
Selected topics in specific areas of computer science. May be repeated for credit when the topic varies.

COMP-SCI 5590AW Special Topics Credits: 1-3
COMP-SCI 5590BD Special Topics Credits: 1-3
COMP-SCI 5590CC Special Topics In Computer Science Credits: 1-3
COMP-SCI 5590CI Special Topics Credits: 1-3
COMP-SCI 5590CN Special Topics Credits: 1-3
COMP-SCI 5590HI Special Topics Credits: 1-3
COMP-SCI 5590MT Special Topics Credits: 1-3
COMP-SCI 5590NN Special Topics Credits: 1-3
Selected topics in specific areas of computer science. May be repeated for credit when the topic varies.

COMP-SCI 5590OS Special Topics Credits: 1-3
COMP-SCI 5590PB Special Topics Credits: 1-3
Special Topics
COMP-SCI 5590PG Special Topics In Computer Science Credits: 1-3
COMP-SCI 5590SA Special Topics In Computer Science Credits: 1-3
COMP-SCI 5590WW Special Topics Credits: 1-3
COMP-SCI 5590WX Special Topics Credits: 1-3
COMP-SCI 5590XX Special Topics Credits: 1-3
COMP-SCI 5590YL Special Topics Credits: 1-3
COMP-SCI 5592 Design and Analysis of Algorithms Credits: 3
Combinatorial analysis, searching and sorting, shortest path algorithms, spanning trees, search and traversal techniques, backtracking, branch and bound, heuristics, algebraic simplification and transformation.

Prerequisites: COMP-SCI 303 and COMP-SCI 404.

COMP-SCI 5596A Computer Security I: Cryptology Credits: 3
Study of theory, and algorithmic techniques, of the fields of number theory and cryptology, as they are applied in the general area of computer and network security.

Prerequisites: COMP-SCI 291.

COMP-SCI 5596B Computer Security II: Applications Credits: 3
Application of the algorithmic techniques learned in COMP-SCI 5596A to provide suitable security countermeasures to the variety of security threats across the spectrum of computing.

Prerequisites: COMP-SCI 5596A.

COMP-SCI 5597 Directed Readings Credits: 1-3
Readings in an area selected by the graduate student in consultation with a faculty member. Arrangements must be made prior to registration.
COMP-SCI 5598 Research Seminar Credits: 1-3
Graduate research based on intensive readings from the current research literature under the direction of a faculty member. Arrangements must be made prior to registration.

COMP-SCI 5599 Research and Thesis Credits: 1-6
A project investigation leading to a thesis, or written report under the direction of a faculty member. A prospectus must be accepted prior to registration.

COMP-SCI 5690 Advanced Special Topics Credits: 1-3
A lecture course presenting advanced research level topics. This course is intended to allow faculty and visiting scholars to offer special courses in selected research areas.
Prerequisites: Ph.D. Candidacy.

COMP-SCI 5690ND Advanced Special Topics Credits: 1-3

COMP-SCI 5697 Directed Readings Credits: 1-3
Readings in an area selected by the doctoral student in consultation with a doctoral faculty member. Arrangements must be made prior to registration.

COMP-SCI 5698 Advanced Research Seminar Credits: 1-3
Advanced research by a group of doctoral students based on intensive readings from the current research literature under the direction of one or more doctoral faculty. Original research results of each student are exchanged by presentations and group discussion. Arrangements must be made prior to registration.

COMP-SCI 5699A Research And Dissertation Research In Computer Science Credits: 1-12
Doctoral research in computer science.

COMP-SCI 5899 Required Grad Enrollment Credit: 1

Computer Sci Electrical Engr Courses

CSEE 5110 Network Architecture I Credits: 3
This course provides an introduction to fundamental concepts and principles in the design and implementation of computer communication networks, their protocols, and architectures. Topics to be covered include: layering, and addressing, naming, routing, internetworking, Internet protocols, reliable transfer, congestion control, link control, multiple media access, and network measurement and management.
Prerequisites: COMP-SCI 421A, COMP-SCI 431.

CSEE 5111 Network Architecture II Credits: 3
In this course, advanced principles, protocols, and architectures of computer networks will be studied with specific emphasis on emerging technologies. The focus will be on the latest networking protocol designs with particular attention to the TCP/IP and application layers.
Prerequisites: CSEE 5110.

CSEE 5113 Network Routing Credits: 3
Algorithms, protocols and analysis for network routing. Routing in different networks such as circuit-switched networks, Internet, broadband networks, and transmission networks are covered.
Prerequisites: CSEE 5110, CSEE 5112.

CSEE 5590 Special Topics Credits: 1-3
This course is intended to allow faculty and visiting scholars to offer special courses in selected topics.

CSEE 5690 Advanced Special Topics Credits: 1-3
A lecture course presenting advanced research level topics. This course is intended to allow faculty and visiting scholars to offer special courses in selected research areas.

CSEE 5697 Directed Readings Credits: 1-3
Readings in an area selected by the doctoral student in consultation with a doctoral faculty member. Arrangements must be made prior to registration.

CSEE 5699 Research and Dissertation Research in Telecommunications and Computer Networking Credits: 1-12
Doctoral Research in Telecommunications and Computer Networking.

CSEE 5899 Required Graduate Enrollment Credit: 1
Required Graduate Enrollment.

Electrical Computer Engr Courses

E&C-ENGR 130 Engineering Graphics Credits: 3
Introduction to Engineering Graphics with the use of the Computer Aided Design tools AutoCAD and SolidWorks. Introduction to 2D design with AutoCAD and introduction to 3D design with SolidWorks. Also an introduction to electrical circuit diagrams. No previous 2D or 3D CAD experience is necessary to take this class.
E&C-ENGR 216 Engineering Computation Credits: 4
Development, analysis and synthesis of structured computer programs for solving engineering problems in the Python and C languages. Introduction to algorithms and data structures.
Prerequisites: MATH 110 or MATH 120 (or higher) or ALEKS score of 51 (or higher); or ACT Math sub-score of 28 or higher; or SAT Math sub-score of 660 or higher.

E&C-ENGR 217 Engineering Computation Credits: 2
Students learn to develop, analyze and synthesize structured computer programs for solving engineering problems in the Python and C languages. This course also provides an introduction to algorithms and data structures. This course is available by approval of the degree program committee if transfer credit has been approved for one of the listed programming languages.
Prerequisites: MATH 110 or MATH 120 (or higher) or ALEKS score of 51 (or higher); or ACT Math sub-score of 28 or higher; or SAT Math sub-score of 660 or higher.

E&C-ENGR 226 Logic Design Credits: 3
Design of combinational logic circuits, logic minimization techniques, design of sequential logic circuits, state machine design techniques, digital system design.
Co-requisites: E&C-ENGR 227.

E&C-ENGR 227 Logic Design Laboratory Credit: 1
Laboratory for E&C-ENGR 226. Experimental topics related to the design of combinational and sequential logic systems and small digital systems.
Co-requisites: E&C-ENGR 226.

E&C-ENGR 228 Introduction to Computer Design Credits: 3
This course covers computer organizations and fundamental computer design techniques. It also discusses design of computer data unit, control unit, input-output, microprogramming. Memory systems (RAM memory, Cache memory, interrupts, secondary memory) and direct memory access design is also discussed. Verilog HDL design is introduced and applied to small digital systems.
Prerequisites: E&C-ENGR 226 and E&C-ENGR 227.
Co-requisites: E&C-ENGR 229.

E&C-ENGR 229 Introduction to Computer Design Laboratory Credit: 1
This laboratory course covers experimental topics related to the design of digital computer systems and arithmetic circuits which students study in the E&C-ENGR 228.
Prerequisites: E&C-ENGR 226 and E&C-ENGR 227.
Co-requisites: E&C-ENGR 228.

E&C-ENGR 241 Applied Engineering Analysis I Credits: 3
Prerequisites: MATH 220 or MATH 268 (with a grade of C or better).

E&C-ENGR 250 Engineering Mechanics and Thermodynamics Credits: 3
This course concentrates on practical concepts in mechanics and thermodynamics for EC-ENGR majors, such as the practical use of forces, moments, couples, centroids, and moment of inertia, friction, manipulating systems of rigid bodies in motion and applying conservation of energy to gases, liquids, and solids. Materials will also be addressed.
Prerequisites: MATH 220 or MATH 266; and PHYSICS 240 (both with a grade of C or better).

E&C-ENGR 276 Circuit Theory I Credits: 3
Kirchoff's circuit laws, Ohm's Law, nodal and mesh analyses, source transformations, superposition, Thvenin and Norton equivalents, transient analysis of 1st and 2nd order systems. AC circuit analysis, phasors, impedance, sinusoidal steady-state responses, operational amplifiers and PSpice.
Prerequisites: PHYSICS 250 and E&C-ENGR 241 (or MATH 345 as a pre or co-req) with a grade of C or better.

E&C-ENGR 277 Circuit Theory I Lab Credit: 1
Introduction to the use and limitations of basic instruments used in electrical testing and measurement. Experimental techniques and laboratory safety. Data gathering, interpretation and presentation. Preparation of laboratory reports. Experimental work supporting theoretical concepts developed in E&C-ENGR 276.
Co-requisites: E&C-ENGR 276.
E&C-ENGR 302 Electromagnetic Waves and Fields Credits: 3
Elements of vector calculus: curl, gradient and divergence differential operations; vector identities; integration of vectors Stokes and Gauss’s theorems, laplacian; review of electrostatic and magnetostatic fields; boundary value problems; boundary conditions; time-harmonic fields and phasors; Maxwell’s equations, Poynting vector; vector and scalar wave equations; electromagnetic wave propagation in free-space, lossy and lossless dielectrics and conductors; polarization; reflections at normal and oblique incidences; transmission line parameters; telegraphers equations; input impedance and VSWR; Smith Chart and impedance matching; transients on transmission lines.
Prerequisites: E&C-ENGR 341R, E&C-ENGR 376.
Co-requisites: E&C-ENGR 303.

E&C-ENGR 303 Electromagnetic Waves and Fields Lab Credit: 1
The goal of the lab is to complement and demonstrate the main concepts of transmission line and microwave theory using hands on experiments. The experiments will introduce students to microwave sources, components, and transmission lines. Moreover, the experiments will demonstrate the concepts of wave propagation, attenuation, power splitting, reflection, and standing waves. Moreover, students will design and conduct experiments to characterize unknown loads and antennas. Recommended preparation: MATLAB knowledge/proficiency.
Prerequisites: E&C-ENGR 302.

E&C-ENGR 330 Electronic Circuits Credits: 3
Application of operational amplifiers, semiconductors device physics, elementary analysis and design of analog electronic circuits that utilize diodes, BJTs, and MOSFETs in single and multistage amplifiers with passive loads and power amplifiers; DC biasing, small signal analysis and calculation of frequency responses. The use of CAD (Spice) in the analysis and design of electronic circuits.
Prerequisites: E&C-ENGR 334.
Co-requisites: E&C-ENGR 331.

E&C-ENGR 331 Electronic Circuits Laboratory Credit: 1
Laboratory experiments in the application of operational amplifiers, the analysis, design, and testing of single and multistage amplifiers with passive loads, and the measurement of frequency response. Recommended preparation: E&C-ENGR 276, E&C-ENGR 277.
Prerequisites: E&C-ENGR 330.

E&C-ENGR 334 Semiconductors and Devices Credits: 3
Junction theory, semiconductor diodes and models, bipolar transistors and models, field-effect transistors and models, selected electron devices and models.
Prerequisites: E&C-ENGR 241, E&C-ENGR 276.

E&C-ENGR 341R Applied Engineering Analysis II Credits: 3
Complex numbers; Euler’s formulas, analytic functions, Taylor and Laurent series; Cauchy residue theorem and application to evaluation of integrals; linear algebra, eigenvalue and eigenvectors; Fourier series and transforms.
Prerequisites: E&C-ENGR 241 (with a grade of C or better).

E&C-ENGR 358 Introduction to Control Systems Credits: 3
Study of feedback techniques, with applications to control systems. Includes modeling, applications of Bode plot, root locus, state-variable, and Nyquist methods.
Prerequisites: E&C-ENGR 376.

E&C-ENGR 376 Circuit Theory II Credits: 3
Power, transformers, three-phase circuits, two-port networks, the theory and application of Laplace Transforms.
Prerequisites: E&C-ENGR 276.
Co-requisites: E&C-ENGR 377.

E&C-ENGR 377 Circuit Theory II Lab Credit: 1
Continuation of E&C-ENGR 277 introducing the use of additional instruments used in electrical testing and measurements. Statistical data evaluation methods. Experimental work supporting concepts developed in E&C-ENGR 376.
Prerequisites: E&C-ENGR 277.
Co-requisites: E&C-ENGR 376.

E&C-ENGR 380 Signals and Systems Credits: 3
Continuous and discrete-time signals and systems, frequency response, Fourier analysis of discrete and continuous signals and systems and use of z, Fourier, Discrete Fourier, and Fast Fourier Transforms.
Prerequisites: E&C-ENGR 341R.
Co-requisites: E&C-ENGR 381.
E&C-ENGR 381 Signals and Systems Lab Credit: 1
Computer Laboratory for E&C-ENGR 380. Various signal processing software programs (MATLAB and DSP) are used to investigate properties and applications of continuous and discrete time signals and systems.
\textbf{Co-requisites:} E&C-ENGR 380.

E&C-ENGR 400 Problems in Electrical and Computer Engineering Credits: 1-4
Analytic or experimental problems pertaining to electrical or computer engineering.
\textbf{Prerequisites:} Departmental consent.

E&C-ENGR 401 Topics In Electrical And Computer Engineering Credits: 1-4
Topics covering current and new technical developments in electrical or computer engineering.
\textbf{Prerequisites:} Senior standing.

E&C-ENGR 401PQ Topics in Electrical Engineering Credits: 1-4
Topics covering current and new technical developments in electrical or computer engineering.
\textbf{Prerequisites:} Senior standing.

E&C-ENGR 402 Senior Design I Credits: 3
This is the first capstone design course in electrical and computer engineering providing and accounting for laboratory, library, research and other work needed for the development of the project and stresses oral presentations.
\textbf{Prerequisites:} E&C-ENGR 330 and (E&C-ENGR 428R or E&C-ENGR 466).

E&C-ENGR 403 Senior Design II Credits: 2
This is the second capstone design course in electrical and computer engineering providing laboratory experience in prototyping, fabrication, and troubleshooting of the design project with stresses in written and oral presentation. Course topics include: project management, professional practice, ethical and engineering economic considerations and development of written and oral presentation skills.
\textbf{Prerequisites:} E&C-ENGR 402.

E&C-ENGR 412 Principles of RF/Microwave Engineering Credits: 3
General aspects of TE, TM and TEM mode propagation in waveguides; circular waveguides; optical waveguides; wave propagation on dielectric backed conductors; wire antennas; equivalence principle and aperture antennas; antenna impedance and mutual coupling in arrays; array beamforming; scattering matrix representations; impedance matching; resonators; filters, couplers and power-dividers; microstriplines and striplines; r.f. propagation in wireless and radar systems; conformal mapping techniques and applications (optional). Recommended preparation: MATLAB proficiency.
\textbf{Prerequisites:} E&C-ENGR 302, E&C-ENGR 380, E&C-ENGR 381.

E&C-ENGR 414 Microwave Engineering for Wireless Systems Credits: 3
Microwave networks; s-, z-, y- and abcd matrices; signal flow graphs; circular waveguides; stripline microstrip characteristics; impedance transformers; power dividers and directional couplers; microwave filters; microwave resonators; active microwave circuits.
\textbf{Prerequisites:} E&C-ENGR 302, E&C-ENGR 380, E&C-ENGR 381, MATLAB proficiency.

E&C-ENGR 415 Microwave Engineering for Wireless Systems Lab Credit: 1
Design performance simulation of microwave filters and active microwave circuits; comparative analysis of impedance transformers; use of CAD tools in microwave circuit design.
\textbf{Prerequisites:} E&C-ENGR 414.

E&C-ENGR 416 Neural and Adaptive Systems Credits: 3
A hands-on introduction to the theory and applications of neurocomputing. Includes classification, function approximation, supervised and unsupervised learning, time series analysis, and adaptive filtering using different feed-forward and recurrent artificial neural networks.
\textbf{Prerequisites:} COMP-SCI 394R, E&C-ENGR 341R.

E&C-ENGR 418 Introduction to Radar Systems Credits: 3
Radar equation; MT, Pulsed Doppler and Tracking Radars; detection of and information from radar signals; radar antennas; transmitters and receivers; radar propagation and clutter.
\textbf{Prerequisites:} E&C-ENGR 302, E&C-ENGR 380, E&C-ENGR 381.

E&C-ENGR 420 Advanced Engineering Computation Credits: 2
Programming and computational analysis principles and techniques for various problems in embedded programming, applied computation, and signal processing.
\textbf{Prerequisites:} E&C-ENGR 216.

E&C-ENGR 426 Microcomputer Architecture and Interfacing Credits: 3
Advanced microprocessor architecture and programming; interfacing and programming of peripherals. Parallel and serial communication, interrupts, direct memory access, coprocessors.
\textbf{Prerequisites:} E&C-ENGR 226.
E&C-ENGR 427 Microcomputer Laboratory Credit: 1
Laboratory for E&C-ENGR 426. Microprocessor hardware and software involving interfacing of peripherals to 8-bit and 16-bit microprocessor. Simple D/A conversion, music composition, and various programmable controllers.
Prerequisites: E&C-ENGR 227.
Co-requisites: E&C-ENGR 426.

E&C-ENGR 428R Embedded Systems Credits: 3
This course examines the hardware/software aspects associated with developing microcontroller-based computer systems. The students learn about the architecture and assembly language for popular microcontrollers and how to take advantage of a variety of input/output options that include binary ports, A/D and D/A converters, communication ports, and interfacing techniques for various applications.
Prerequisites: E&C-ENGR 426, E&C-ENGR 427.
Co-requisites: E&C-ENGR 429.

E&C-ENGR 429 Embedded Systems Laboratory Credit: 1
The laboratory introduces the students to a variety of challenging design projects using microcontroller interfacing techniques to develop real world applications, such as digital thermometer and digital pressure monitoring systems. Students must produce an individual design project.
Prerequisites: E&C-ENGR 426, E&C-ENGR 427.
Co-requisites: E&C-ENGR 428R.

E&C-ENGR 436 Power Electronics I Credits: 3
Power electronic device characteristics, important circuit and component concepts, phase controlled rectifiers, line communicated inverters and AC phase control. Includes laboratory projects.
Prerequisites: E&C-ENGR 330.

E&C-ENGR 442 Introduction to VLSI Design Credits: 3
The goal of this course is to familiarize students with the design fundamentals and layout of Very Large Scale Integrated (VLSI) Circuits. The primary focus of this course is complementary MOSFET (CMOS) based digital integrated circuits design and analysis. However, the topics regarding transistor, interconnect, and circuit implementation are relevant to digital, analog and mixed-signal integrated circuits. This course is designed to be a comprehensive foundation for advanced micro- and nano-electronics courses. To familiarize the students with the realities of design complexities they will get exposure to commercial CAD tools in a separate lab co-requisite class. Recommended preparation: Basic Electronics.
Prerequisites: E&C-ENGR 330.

E&C-ENGR 443 Introduction to VLSI Design Laboratory Credits: 3
The goal of this course is to teach basic design concepts and implementation issues of digital integrated circuits. Various methods of designing and optimizing very large scale integrated (VLSI) circuits will be introduced in the lab projects. To familiarize students with the realities of integrated circuit design and layout, they will get exposure to industry-standard computer aided design (CAD) and simulation tools for VLSI circuits and systems. The students will be using these CAD tools in the following levels – schematic, layout, parasitic extraction, and circuit simulation.
Co-requisites: E&C-ENGR 330.

E&C-ENGR 453 Introduction to Wind Energy Systems Credits: 3
This course explores the power conversion and control of wind energy conversion systems (WECS) from the electrical engineering perspective. It provides a comprehensive and in-depth analysis of wind as a source of energy, aerodynamic of wind turbine, wind generators, system configurations, power converters, control schemes, and system design of various practical wind energy systems.
Prerequisites: E&C-ENGR 376

E&C-ENGR 455 Instrumentation and Control Credits: 3
The instrumentation and control of industrial processes and systems, introduction to Programmable Logic Controllers, and simulation modeling of various systems.
Prerequisites: E&C-ENGR 358.

E&C-ENGR 457 Fundamentals of Solar Photovoltaic Cells Credits: 3
The science and engineering of solar cell/solar photovoltaic (PV) spans several disciplines namely physics, chemistry, electronic and electrical engineering. Even though solar cell related researches are carried out in those traditional disciplines but it is not widely taught as a comprehensive course. This course highlights the fundamental science and engineering of solar PV devices, solar energy conversion as well as solar cell manufacturing issues. It covers from basic to modern solar PV devices, including typical solar cell materials, basic device physics, ideal and non-ideal models, device parameters and design, and device fabrication.
Prerequisites: E&C-ENGR 330 or E&C-ENGR 334.
E&C-ENGR 458 Automatic Control System Design Credits: 3
Techniques for feedback system design analysis: compensator design examples, state variable methods, non-linear systems, and sampled-data control systems.
**Prerequisites:** E&C-ENGR 380, E&C-ENGR 358.

E&C-ENGR 459 Introduction to Photovoltaic Systems Credits: 3
The course presents an updated background of world energy production and consumption, a summary of the solar spectrum, how to locate the sun, and how to optimize the capture of its energy, as well as the various components that are used in PV systems. Also studied are why certain photovoltaic (PV) designs are used in certain ways, as well as how the design process is implemented. Economic and environmental issues involved in PV design criteria are discussed along with the most recently available technology, design, and installation practices.

E&C-ENGR 460 Introduction to Power Systems Credits: 3
Magnetic circuitry in general and in machinery; DC machine theory, operation, applications, transformer circuits, synchronous machine theory, operation applications, basic principles of energy conversion, introduction to power electronics, and basic principles of power transmission and control.
**Prerequisites:** E&C-ENGR 376.

E&C-ENGR 463 Advanced Sustainable Energy Systems Engineering Credits: 3
Sustainable Energy Systems Engineering focuses on understanding the theory and application of emerging energy technologies, including solar, wind, biomass, oceanic, geothermal, hydropower, fuel cell (hydrogen), nuclear, and other more exotic energy sources. A premise of the course is that a sustainable energy technology must both be technically feasible and economically viable. Renewable energy sources will be highlighted with a focus on projections for a sustainable energy future. Graduate students will be assigned an additional project to work.
**Prerequisites:** E&C-ENGR 466.

E&C-ENGR 466 Power Systems I Credits: 3
Electric power system fundamentals, rotating machines in general, synchronous, induction and DC machines, methods of power system analysis and design, modeling of power systems components such as transmission lines, transformers and generators, and analysis of steady state operation of power system under balanced conditions.
**Prerequisites:** E&C-ENGR 376.

E&C-ENGR 467 Power Systems II Credits: 3
This course includes the following topics: power system matrices, power flow analysis, Gauss-Seidel and Newton-Raphson techniques, fast-decoupled load flow, economic dispatch, voltage control system, and power system control. Prerequisites: E&C-ENGR 466.

E&C-ENGR 468 Electric Power Distribution Systems Credits: 3
Operation and design of utility and industrial distribution systems including distribution system planning; load characteristics; application of distribution transformers; design of subtransmission lines, distribution substations, primary systems, secondary systems; application of capacitors; voltage regulation and reliability.
**Prerequisites:** E&C-ENGR 466.

E&C-ENGR 474 Introduction to Communication Systems Credits: 3
This course is an introduction to principles and fundamentals of communication systems and covers the following topics: signal representation and analysis, analog and digital modulation techniques, error control channel coding, properties of communications media, and overview of modern systems and latest cellular technology.
**Prerequisites:** COMP-SCI 394R, E&C-ENGR 380.

E&C-ENGR 477 Introduction to Wireless Networking Credits: 3
Principles of the design and analysis of wireless networks. Study of medium access control, administration routing and adaptation to the complexities of the wireless environment. Investigation of networking issues in the IEEE 802.11 family of standards, IEEE 802.15 (Bluetooth), Long Term Evolution, cellular, satellite, ad hoc, and sensor networks.
**Prerequisites:** COMP-SCI 394R.

E&C-ENGR 479 Introduction to Computer Vision Credits: 3
This course focuses on topics of computer vision, teaching computers how to understand images. Introductory topics include image formation, color and texture features, homograph, key points detection, aggregation, subspace methods in image modeling, and deep learning based image segmentation and classification, with applications in photography, media and entertainment, education, defense and medicine. The course is project based and emphasis hands on experiences for students to solve real world problems.
**Prerequisites:** E&C-ENGR 380

E&C-ENGR 480 Digital Signal Processing Credits: 3
Concepts, analytic tools, design techniques used in computer processing of signals: signal representation, sampling, discrete-time system analysis, recursive/non-recursive filters, design/implementation of digital filters.
**Prerequisites:** E&C-ENGR 380.
E&C-ENGR 484 Digital Image Processing
Credits: 3
Fundamentals of digital image processing hardware and software, including digital image acquisition, display, compression, transforms and segmentation. Recommended preparation: Experience in a high-level programming language.
Prerequisites: E&C-ENGR 380.

E&C-ENGR 486 Pattern Recognition
Credits: 3
Pattern recognition techniques of applications such as automatic recognition for speech, visual inspection systems, clinical medicine, automatic photographic recognition systems and advanced automation systems.
Prerequisites: E&C-ENGR 380.

E&C-ENGR 491 Internship
Credits: 0-6
Students may participate in structured internships under the joint supervision of an employer and a faculty member. The student must carry out significant professional responsibilities that also have academic merit. The number of credit hours is based on the quality of the academic experience. Available for credit/nocredit only; petition forms for E&C-ENGR 491 internships are available in the office of CSEE Division and on the web.
Prerequisites: At least 18 hours of EC-ENGR courses toward the degree.

E&C-ENGR 497 Directed Readings
Credits: 1-4
Readings in an area selected by an undergraduate student in consultation with a faculty member. Arrangements must be made prior to registration.
Prerequisites: Departmental consent.

E&C-ENGR 499 Undergraduate Research
Credits: 1-3
Completion of a project, including a final written report, under the direction of a faculty member. A prospectus must be accepted prior to registration.
Prerequisites: Departmental consent.

E&C-ENGR 5316 Artificial Neural and Adaptive Systems
Credits: 3
This graduate course is a hands-on introduction to theory and applications of neurocomputing, including: classification, function approximation, supervised and unsupervised learning, time series analysis, and adaptive filtering using different feed-forward and recurrent artificial neural networks.
Prerequisites: E&C-ENGR 341R (or COMP-SCI 5590CI).

E&C-ENGR 5318 Dynamical Systems and Complex Networks
Credits: 3
An overview of classical dynamical systems, and its application in different fields such as Electrical Engineering (nonlinear circuits), Network Sciences, Epidemiology, and Ecology will be discussed. Phenomena such as chaos, bifurcation, and limit cycles will be examined. This course will also introduce and develop the mathematical theory of Complex Networks with applications to network-driven phenomena in the Internet, search engines, social networks, the World Wide Web, information and biological networks; spectral graph theory; models of networks including random graphs, preferential attachment models, and the small-world models.

E&C-ENGR 5501AP Special Topics In Electrical Engineering
Credits: 1-4

E&C-ENGR 5501NN Special Topics In Electrical Engineering
Credits: 1-4

E&C-ENGR 5512 Microwave Remote Sensing
Credits: 3
Basic principles of remote sensing including scattering, absorption, transmission, and reflection of microwave energy, Basic radiative transfer theory. Microwave remote sensing systems including altimeters, scatterometers, radiometers, synthetic-aperture systems. Principle applications of remote sensing systems including imaging, atmospheric sounding, oceanographic monitoring, ice-sheet dynamics, etc.
Prerequisites: E&C-ENGR 414.

E&C-ENGR 5513 Advanced Principles of RF/Microwave Engineering
Credits: 3
General aspects of TE, TM and TEM mode propagation in waveguides; circular waveguides; optical waveguides; wave propagation on dielectric backed conductors; wire antennas equivalence principle and aperture antennas; antenna impedance and mutual coupling in arrays; array beamforming; scattering matrix representations; impedance matching; resonators; filters, couplers and power-dividers; microstriplines and striplines; r.f. propagation in wireless and radar systems; conformal mapping techniques ad applications (optional). Recommended preparation: Knowledge in Engineering Computation, Technical Writing Skills.
Prerequisites: E&C-ENGR 302, E&C-ENGR 380, E&C-ENGR 381.

E&C-ENGR 5516 Computer Networks
Credits: 3
Concepts and goals of computer networking, structure of computer networks, OSI model and layers, network control, analysis, design and management, data communication techniques including fiber optics, WAN, MAN and LAN architecture and protocols, internetworking, case studies and hand-on studying the performance by analytic modeling and computer simulation.

E&C-ENGR 5518 Advanced Radar Systems & Techniques
Credits: 3
Radar equation; MLI, Pulsed Doppler and Tracking Radars; Detection of and information from Radar Signals; Radar Antennas, Transmitters and Receivers; Radar Propagation and clutter.
Prerequisites: E&C-ENGR 302, E&C-ENGR 380.
E&C-ENGR 5528 Advanced Embedded Systems Credits: 3
This course examines the hardware/software aspects associated with developing microcontroller-based computer systems. The students learn about the architecture and assembly language for popular microcontrollers and how to take advantage of a variety of input/output options that include binary ports, A/D and D/A converters, communication ports, and interfacing techniques for various applications. Graduate students are required to do Embedded Systems lab experiments.
Prerequisites: E&C-ENGR 426, E&C-ENGR 427.

E&C-ENGR 5530 Digital Electronics Credits: 3
Electronic hardware aspects of digital systems. Includes state-of-the-art information on integrated-circuit logic devices and their applications.

E&C-ENGR 5532 Biomedical Instrumentation Credits: 3
Biomedical objectives, physical and engineering principles; optimal equipment design and actual performance of biomedical instrumentation; considers practical instrumentation problem solutions and unsolved problems.
Prerequisites: E&C-ENGR 330.

E&C-ENGR 5533 Analog Integrated Circuit Design Credits: 3
This course will cover the analysis and design of analog and mixed signal integrated circuits, with an emphasis on design principles for realizing state-of-the-art analog circuits. The course will provide the critical concepts by giving physical and intuitive explanations in addition to the quantitative analysis of important analog building block circuits. First-order hand calculations and extensive computer simulations are utilized for performance evaluation and circuit design. Students will be required to complete a final project which will involve the design at the layout level of an analog circuit. Successful designs will be fabricated through the MOSIS Educational Service.
Prerequisites: E&C-ENGR 276, E&C-ENGR 330.

E&C-ENGR 5534 Computer Arithmetic Credits: 3
Computer arithmetic is a sub field of digital computer organization. It deals with the hardware realization of arithmetic functions to support various computer architectures as well as with arithmetic algorithms for firmware/software implementation. A major thrust of digital computer arithmetic is the design of hardware algorithms and circuits to enhance the speed of various numeric operations. Verilog HDL is used as tool to simulate the algorithms and circuits.
Prerequisites: E&C-ENGR 226, E&C-ENGR 5535.

E&C-ENGR 5535 Hdl-Based Digital Systems Design Credits: 3
This course covers hardware design techniques using a Hardware Description Language (HDL). It also discusses several digital system design methodologies, including structural specifications of hardware, HDL-based simulations and testbenches. Courses focus on the synthesis methodologies for use-defined primitives (UPD), data types, operators, Verilog constructs multiplexed datapaths, buses, bus drivers, FSMs, assignments, case, functions, tasks, named events and rapid prototyping techniques with Verlog HDL, ASICS and FPGAs.
Prerequisites: E&C-ENGR 226.

E&C-ENGR 5536 Power Electronics II Credits: 3
Circuit concepts and analysis techniques for transistor switching regulators, thyristor choppers, transistor inverters, self-commutated thyristor inverters and cycloconverters.
Prerequisites: E&C-ENGR 436.

E&C-ENGR 5537 Mixed-Signal Integrated Circuit Design Credits: 3
Modern integrated circuit design often requires the integration of analog and digital circuits on the same chip. This integration provides numerous advantages over purely analog or digital approaches. This course will cover the analysis and design of mixed-signal integrated circuits and will address the challenges of having both analog and digital circuits on the same substrate. Important mixed-signal circuits such as data converters and filters will be studied in detail.
Prerequisites: E&C-ENGR 5533.

E&C-ENGR 5542 Introduction to VLSI Design Credits: 3
With a focus on CMOS Digital technology this course covers the basic concepts of integrated circuits, various methods of designing VLSI circuits, and techniques to analyze performance metrics (speed, area, power and noise). Clocking, interconnect and scaling issues of integrated circuit will also be discussed. It will cover device, interconnect and circuit level implementation issues of both logic and memory circuits. To familiarize students with the realities of design complexities and layout environment they will get exposure to VLSI CAD tools in the following levels - schematic, layout, extraction and circuit simulation through the labs and projects.

E&C-ENGR 5553 Wind Energy System Engineering Credits: 3
This course explores the power conversion and control of wind energy conversion systems (WECS) from the electrical engineering perspective. It provides a comprehensive and in-depth analysis of wind as a source of energy, aerodynamic of wind turbine, wind generators, system configurations, power converters, control schemes, and system design of various practical wind energy systems.

E&C-ENGR 5556 Advanced Instrumentation and Control Credits: 3
The instrumentation and control of industrial processes and systems. Introduction to Programmable Logic Controllers. Simulation modeling of various systems.
Prerequisites: E&C-ENGR 358 (or MEC-ENGR 415).
E&C-ENGR 5557 Fundamentals of Solar Photovoltaic Cells Credits: 3
The science and engineering of solar cell/solar photovoltaic (PV) spans several disciplines namely physics, chemistry, electronic and electrical engineering. Even though solar cell related researches are carried out in those traditional disciplines but it is not widely taught as a comprehensive course. This course highlights the fundamental science and engineering of solar PV devices, solar energy conversion as well as solar cell manufacturing issues. It covers from basic to modern solar PV devices, including typical solar cell materials, basic device physics, ideal and non-ideal models, device parameters and design, and device fabrication.

E&C-ENGR 5558 Automatic Control System Design Credits: 3
Techniques for feedback system design and analysis; computational aids, compensator design and examples, state variable methods, non-linear systems, ad sampled-data control systems.
Prerequisites: E&C-ENGR 226, E&C-ENGR 358.

E&C-ENGR 5559 Introduction to Photovoltaic Systems Credits: 3
The course presents an updated background of world energy production and consumption, a summary of the solar spectrum, how to locate the sun and how to optimize the capture of its energy, as well as the various components that are used in PV systems. Some section of the course has also been added to explain why certain photovoltaic (PV) designs are done in certain ways, as well as how the design process is implemented. Economic and environmental issues as PV design criteria are discussed along with the most recently available technology and design and installation practice.

E&C-ENGR 5560 Electric Power Distribution Systems Credits: 3
Operation and design of utility and industrial distribution systems including distribution system planning; load characteristics; application of distribution transformers; design of subtransmission lines, distribution substations, primary systems, secondary systems, Smart Grid; application of capacitors; voltage regulation and reliability.
Prerequisites: E&C-ENGR 466.

E&C-ENGR 5563 Sustainable Energy System Engineering Credits: 3
This course focuses on understanding the theory and application of emerging energy technologies, including solar, wind, biomass, oceanic, geothermal, hydropower, fuel cell (hydrogen), nuclear, and other more exotic energy sources. A premise of the course is that a sustainable energy technology must both be technically feasible and economically viable. We consequently investigate the above energy technologies and the technological promise, progress, and application of each energy source, as well as its economic opportunities and challenges. Renewable energy sources will be highlighted with a focus on projections for a sustainable energy future.

E&C-ENGR 5565 Auxiliary Electric System Design Credits: 3
This course provides design, operation, contingency analysis and black start requirements of an Auxiliary Electric System (AES) for a coal fired power plant using industry standards (IEEE-666, NEMA MG-1, ANSI C57 and C37 as well as relevant IEC).
Prerequisites: E&C-ENGR 466 or Department Approval.

E&C-ENGR 5567 Power Systems II Credits: 3
This course covers power system matrices, power flow analysis, Gauss-Seidel and Newton-Raphson techniques, fast-decoupled load flow, economic dispatch, transient stability and operation, and power system control.
Prerequisites: E&C-ENGR 358, E&C-ENGR 466.

E&C-ENGR 5568 Economics of Power Systems Credits: 3
Transmission loss formula coefficients, incremental costs and losses, economic scheduling of generation, and applications.
Prerequisites: E&C-ENGR 466, E&C-ENGR 467.

E&C-ENGR 5569 Reliability of Electric Power Systems Credits: 3
Development and use of mathematical models for the calculation and estimation of various measures of reliability in electric power systems, Reliability restoration times and cost assessment of generation, transmission, distribution and composite systems are analyzed.
Prerequisites: COMP-SCI 394R.

E&C-ENGR 5570 Principles of Digital Communication Systems Credits: 3
Principles of random processes, information sources and source coding, modulation and demodulation, block and convolutional error control coding, and equalization.
Prerequisites: COMP-SCI 394R, E&C-ENGR 380.

E&C-ENGR 5572 Antennas & Propagation For Wireless Systems Credits: 3
This course introduces the mathematical aspects of the basic antenna parameters such as vector potential, gain, directivity, impedance, radiation patterns, and develops a comprehensive theory of antenna arrays including the effects of mutual coupling. In-depth modeling studies for wire, aperture and microstrip antennas, is presented; diffraction of plane electromagnetic (TE and TM) waves by perfectly conducting half-planes and wedges-applications to site-specific propagation path modeling in wireless systems.
Prerequisites: E&C-ENGR 341R, E&C-ENGR 412.
E&C-ENGR 5573 Advanced Electric Power Lab Credits: 3
Advanced applications of concepts experienced in Generating Plants, Substations and Power Plants of fundamentals and concepts of power systems to practical power plan and industrial applications. Operational limitations of all components of power system equipment. Single and Three Phase Circuits, Generators/Alternators, Transformers, Motors, and specialty items (Coronal mass Ejection, Ferroresonance, System Protection).
Prerequisites: E&C-ENGR 466 and Consent of the Department.

E&C-ENGR 5577 Wireless Communications Credits: 3
Principles of the design and analysis of wireless communications, Study of propagation mechanisms, statistical characterization of wireless channels, diversity and MIMO, spread spectrum and CDMA, Orthogonal Frequency Division Multiplexing (OFDM).
Prerequisites: COMP-SCI 394R.

E&C-ENGR 5578 Multimedia Communication Credits: 3
Visual communication is dominating the Internet and mobile networks. This class covers topics on video signal processing, modeling, compression, and communication. Includes information theory foundations on source coding, lossless coding schemes, video coding framework, as well as the current status of video coding standards and multimedia communication systems.
Prerequisites: COMP-SCI 394R

E&C-ENGR 5579 Digital Signal Processing in Telecommunications Credits: 3
Applications of digital signal processing in telecommunications systems; oversampling and quantization, Delta-Sigma modulation, linear predictive speech coding, adaptive filtering, echo canceller, adaptive receivers and equalizers for wireless communication, digital cellular, CDMA.
Prerequisites: E&C-ENGR 474, E&C-ENGR 480.

E&C-ENGR 5580 Digital Signal Processing Credits: 3
Analysis and representation of discrete-time signals and systems including a discussion of discrete-time convolution, difference equations, the z-transform and the discrete Fourier transform. Similarities with and distinctions between discrete-time and continuous-time signals and systems. Digital network structures for implementation of both recursive (infinite impulse response) and nonrecursive (finite impulse response) digital filters. FFT (Fast Fourier Transform) algorithm for computation of the discrete Fourier transform. Graduate students will be expected to successfully complete a number of additional projects as compared with E&C-ENGR 480.
Prerequisites: E&C-ENGR 380.

E&C-ENGR 5582 Computer Vision Credits: 3
The image is an essential form of information representation and communication in modern society. This course focuses on topics of computer vision, teaching computer how to understand images. Topics include image formation, color and texture features, key points detection, aggregation, subspace methods in image modeling, and deep learning image classification, with many applications in photography, media and entertainment, education, defense and medicine.
Prerequisites: E&C-ENGR 380 and prior experience with MATLAB.

E&C-ENGR 5584 Advanced Digital Image Processing Credits: 3
Fundamentals of applied grayscale digital image processing, image sensing and acquisition and quantization, basic set and discrete convolution operations with images, intensity transformations and spatial domain filtering via convolutional masks (smoothing, Laplacian and gradient masks), frequency domain filtering via the two-dimensional discrete transform, two-dimensional sampling and Nyquist theory, frequency domain filtering using lowpass/highpass, rectangular, round, Guassian and Butterworth filters, image restoration using noise filtering via mean order-statistic and adaptive filters, bandpass, band reject and notch filters, Weiner filters, image deblurring filters, computed aided tomography (i.e. CAT scans), morphological image processing and image segmentation.
Prerequisites: E&C-ENGR 380 and prior experience with MATLAB.

E&C-ENGR 5586 Pattern Recognition Credits: 3
Decision functions, distance measures, minimum distance classifiers, hard clustering methods, fuzzy clustering methods, statistical pattern recognition methods, Bayesian classifiers, error probabilities, estimation of density functions, perceptrons, least-mean-square algorithms, feature selection, dimensionality reduction and syntactic pattern recognition.
Prerequisites: COMP-SCI 394R (or STAT 436), a course in high-level programming language.

E&C-ENGR 5588 Communication Theory I Credits: 3
Generalized communication systems, signal processing, signals as random processes, optimum receivers.
Prerequisites: COMP-SCI 394R, a statistics course.

E&C-ENGR 5590 Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590AC Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590AD Special Topics In Electrical And Computer Engineering Credits: 1-4
Special Topics in Electrical and Computer Engineering
E&C-ENGR 5590AE Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590AN Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590AR Special Topics In Electrical And Computer Engineering Credits: 1-4
Special Topics in Electrical and Computer Engineering
E&C-ENGR 5590AS Special Topics in Electrical and Computer Engineering Credits: 1-4
E&C-ENGR 5590AV Special Topics in Electrical and Computer Engineering Credits: 1-4
E&C-ENGR 5590AW Special Topics in Electrical and Computer Engineering Credits: 1-4
E&C-ENGR 5590B Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590BB Special Topics in Electrical and Computer Engineering Credits: 1-4
E&C-ENGR 5590BE Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590BI Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590BP Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590C Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590CA Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590CD Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590CI Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590CL Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590CN Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590CS Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590CT Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590DC Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590DE Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590DS Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590EN Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590ER Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590ES Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590ET Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590FC Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590HF Special Topics in Electrical and Computer Engineering Credits: 1-4
E&C-ENGR 5590IC Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590IE Special Topics Credits: 1-4
E&C-ENGR 5590IN Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590IP Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590IR Special Topics in Electrical and Computer Engineering Credits: 1-4
E&C-ENGR 5590MC Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590ML Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590MS Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590MW Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590NA Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590NG Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590NM Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590NN Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590NR Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590NT Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590ON Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590OT Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590PB Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590PD Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590PG Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590PL Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590PL2 Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590PL3 Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590PQ Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590PR Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590PS Special Topics in Electrical and Computer Engineering Credits: 1-4
E&C-ENGR 5590PV Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590RD Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590RE Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590RF Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590SC Special topics in Electrical and Computer Engineering
E&C-ENGR 5590SL Special Topics in Electrical and Computer Engineering Credits: 1-4
E&C-ENGR 5590SP Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590T Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590TC Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590VL Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590WC Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590WW Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5590WX Special Topics Credits: 1-3
E&C-ENGR 5590XX Special Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5597 Directed Readings Credits: 1-3
Readings in an electrical and computer engineering areas selected by the graduate student in consultation with a faculty member. Arrangements must be made prior to registration.
E&C-ENGR 5598 Research Seminar Credits: 1-3
Graduate research and/or readings in an electrical and computer engineering area selected by the graduate student in consultation with a faculty member. Arrangements must be made prior to registration.
E&C-ENGR 5599 Research Credits: 1-6
Independent investigation in field of electrical engineering to be presented in the form of a thesis.
E&C-ENGR 5600 Problems Credits: 2-5
Supervised investigation in electrical engineering to be presented in form of report.
E&C-ENGR 5606 Electromagnetic Scattering and Antenna Theory Credits: 3
Dyadic analysis; integral equations and Green's functions; field theorems-uniqueness, induction equivalence, reciprocity; image and Babinet's Principles; applications to antennas; method of stationary phase and applications to aperture antennas; array antennas and mutual coupling analysis; method of moments; asymptotic techniques and applications to EM scattering from wedges, cylinders, and spheres; RF propagation path loss modeling and conformal antennas.
Prerequisites: E&C-ENGR 412.
E&C-ENGR 5616 Parallel and Distributed Processing Credits: 3
Covers the fundamental issues involved in designing and writing programs for simultaneous execution. Semaphores and monitor constructs are covered to provide a basis for critical section programming. Expansion of these concepts provide a basis for the analysis and design of control systems for multiprocessor devices and computer networks.
Prerequisites: A systems programming course.
E&C-ENGR 5617 Neural Network Based Computing System Credits: 3
The course will consider computing systems based on neural networks and learning models, along with implementations and applications of such systems.
E&C-ENGR 5618 Artificial Intelligence Credits: 3
Concepts, theories, and models pertaining to neural nets, pattern recognition, learning systems, and programmed problem solving.

E&C-ENGR 5619 Theory of Automata Credits: 3
Sequential machines: Turing machines; deterministic and stochastic automata; applications of automata.

E&C-ENGR 5624 Digital Software Systems Design Credits: 3
Characteristics and parameters of various software subsystem including assemblers, compilers, utility programs, special programming packages, interpreters, and operating systems; and principles of organization into efficient systems.

E&C-ENGR 5633 Nanoelectronics II: Nanoscale Integration & Manufacturing Credits: 3
This course is continuation of Nanoscale Devices and circuits course offered in Fall 2016. In this course students will learn theory about semiconductor processing, and their applications. Limitations of existing process techniques will be discussed, and advances in both physical implementation and circuit/integration techniques will be introduced. Some example of topics that will be covered are: optical lithography, EUV lithography, nanoimprint, implantation, manufacturing aware circuit design, etc. The laboratory work will include modeling and simulation with state-of-the-art semiconductor processing and device simulation tools such as: SRIM, Sentaurus TCAD Process, Sentaurus TCAD Device, etc. Research intensive course.

Co-requisites: E&C-ENGR 5542.

E&C-ENGR 5635 VLSI Systems Design Credits: 3
Course discuss design of the MOSFETs (nFETs and pFETs), and high speed CMOS cascades in VLSI. It also covers the design of various arithmetic circuits, different fast adders, memories, and chip-level physical designs requirements in the VLSI subsystems are also the focus of this course. It uses Verilog HDL/VHDL as a tool to design VLSI systems.

Prerequisites: E&C-ENGR 5535 (or knowledge of VHDL).

E&C-ENGR 5642 Advanced VLSI Design Credits: 3
Course focuses on the issues and challenges of high performance VLSI circuits and systems. The course will be based on papers published in accredited journals and conference proceedings. The goals of this course: (1) Familiarize students with the current and emerging trends, issues and design alternatives of deep submicron and nanoscale IC technologies; (2) Help students acquire the knowledge and skills required for graduate study and research, and professional careers in IC industry; and (3) Teach students how to collect and survey technical materials, develop new research ideas, write research papers, and present technical contents in front of an audience.

E&C-ENGR 5644 Liapunov and Related Nonlinear Methods in Automatic Control Credits: 3
A study of nonlinear methods in automatic control including phase plane analysis, describing function techniques, basic definitions and theorems of Liapunov; methods of generating Liapunov functions, applications of Liapunov's methods, and Popov's methods.

E&C-ENGR 5645 Optimal Control Theory Credits: 3
Analysis and design of dynamic systems using optimal control theory parameter optimization, dynamic optimization, computational methods, differential games.

E&C-ENGR 5646 Stochastic Optimal Estimation and Control Credits: 3
Surveys random process theory; stochastic control and optimization; estimation and filtering based on Kalman-Bucy techniques; stochastic stability; adaptive and learning control systems.

E&C-ENGR 5647 Emerging Interdisciplinary Research in Nanotechnology Credits: 3
This cross-disciplinary course will focus on nanoscale materials, devices and circuit technologies, and its applications in the next generation computing, communication, electronics, biomedical, energy and environment sectors. The course will familiarize students with recent technological progresses and potential socio-economic impacts in the broader fields of nanotechnology. This will be a high level graduate course for students from diverse academic backgrounds. Instructor's prior approval is recommended.

E&C-ENGR 5660 Power-Systems Stability Credits: 3
Performance of synchronous machines under transient conditions, power system stability, system fault computations using symmetrical components; computer solutions of power system problems.

E&C-ENGR 5661 Solid State Energy Conversion Credits: 3
Solid state direct energy conversion; and design of thermoelectric generators and heat pumps.

E&C-ENGR 5662 Power Electronic Drives Credits: 3
Advanced study of dc and ac motor drives controlled by power electronic methods, including phase controlled rectifier de chopper, cycloconverter, variable frequency inverters.

Prerequisites: E&C-ENGR 5536.

E&C-ENGR 5664 Lightning and Switching Surges in Power Systems Credits: 3
Overvoltage, switching surge and lightning effects of a power system. Use of grounding and lightning arresters. Effects of surges off and on machines.

Prerequisites: E&C-ENGR 466 (or equivalent), E&C-ENGR 467 (or equivalent).
E&C-ENGR 5668 Advanced Computer Methods in Power System Analysis Credits: 3
Power system matrices. Sparse matrix methods. Advanced load flow analysis techniques and concepts. Contingency analysis. State estimation. **Prerequisites:** E&C-ENGR 466, strong background in FORTRAN or C.

E&C-ENGR 5670 Direct Current Power Systems Credits: 3
Characteristic and performance analysis of DC transmission lines and associated conversion systems.

E&C-ENGR 5672 Power Systems Relaying Credits: 3
Theory of relaying systems for power system protection, improvement of power system stability. Relay coordination; performance of relays during transient swings and out-of-step conditions. **Prerequisites:** E&C-ENGR 466.

E&C-ENGR 5674 Machine Intelligence Credits: 3
Formal languages in relation to natural language processing; formal languages, graphs, and image processing; formal logic and automated theorem proving; natural language processing; aspects of problem solving and heuristic programming.

E&C-ENGR 5675 Introduction to the Modeling and Management of Uncertainty Credits: 3
Theoretical and practical issues in the modeling and management of uncertainty. Topics include probabilistic uncertainty, belief theory and fuzzy set theory. Applications to computer vision, pattern recognition and expert systems.

E&C-ENGR 5676 Advanced Electric Circuit Analysis Credits: 3
Specialized study of mathematical analysis as applied to solutions of circuit networks with fixed and variable parameters.

E&C-ENGR 5677 Network Synthesis Credits: 3
Surveys linear active and nonreciprocal circuit elements, reliability conditions, methods for synthesizing active networks, and practical applications. **Prerequisites:** E&C-ENGR 5676.

E&C-ENGR 5680 Digital and Sample-Data Systems Credits: 3
Introduces sampling and quantization, design of digital and sample-data systems, digital filters, adaptive sampling and quantization. **Prerequisites:** E&C-ENGR 480.

E&C-ENGR 5681 Applications Of Transforms Credits: 3
Applications of Laplace and other transform methods of solution of circuit and field problems.

E&C-ENGR 5682 Coding Theory II Credits: 3
Further study of error-correcting codes; ring and cyclic codes, linear switching circuits, burst error codes, codes for arithmetic units, etc. **Prerequisites:** E&C-ENGR 5579.

E&C-ENGR 5688 Communication Theory II Credits: 3
Probability theory of analog and digital communication in the presence of random process noise. Encoding systems, detection systems, optimum receivers.

E&C-ENGR 5690 Advanced Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5690EM Advanced Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5690ET Advanced Topics In Electrical And Computer Engineering Credits: 1-4
E&C-ENGR 5690ND Special Topics in Electrical and Computer Engineering Credits: 1-3
E&C-ENGR 5697 Advanced Directed Readings Credits: 1-5
Advanced readings in an electrical and computer engineering area selected by the graduate student in consultation with a faculty member. Arrangements must be made prior to registration.

E&C-ENGR 5698 Advanced Research Seminar Credits: 1-5
Advanced Graduate research and/or readings in an electrical and computer engineering area selected by the doctoral student in consultation with a faculty member. Arrangements must be made prior to registration.

E&C-ENGR 5699 Dissertation Research Credits: 1-9
Doctoral Dissertation

**Information Technology Courses**

INFO-TEC 222 Multimedia Production and Concepts Credits: 3
Multimedia production and concepts will give an overview of multimedia technology and communication theory needed to deliver information and to produce interactive presentations for the web, portable media, and for in-person presentations and demos. The course offers exposure to software, hardware, other multimedia technologies, authoring and copyright matters. **Prerequisites:** COMP-SCI 101.
INFO-TEC 321 Introduction to Computing Resources Administration Credits: 3
This introductory course is designed to give an overview of a wide variety of technical, interpersonal, documentation, and managerial skills needed to become an effective systems administrator.
**Prerequisites:** COMP-SCI 201R.

INFO-TEC 372 Database Administration Credits: 3
This course covers, database administration, setup and tuning of DBMS. Not for Graduate credit.
**Prerequisites:** COMP-SCI 303.

INFO-TEC 426 Practical Network Security Credits: 3
This course examines common threats to computer network security and discusses various techniques to mitigate those threats. The course material is supplemented with lab assignments that implement network security tools and use them to build a small secure network. It discusses information hiding, traffic monitoring and control, intrusion detection, and security policy. Note: NOT FOR GRADUATE CREDIT.
**Prerequisites:** COMP-SCI 420.

INFO-TEC 429 Introduction to Cybersecurity Credits: 3
This course introduces students to cybersecurity and its domains. The course will cover topics such as cryptography, software development security, access control, security architecture, security operations, disaster recovery, and physical and environmental security.
**Prerequisites:** INFO-TEC 321.

INFO-TEC 490 Special Topics Credits: 1-3
Selected topics in specific areas of Information Technology/ Computer Science. May be repeated for credit when the topic varies.
**Prerequisites:** Departmental consent.

INFO-TEC 490DC Introduction to Data Compression Credits: 3
This course provides an introduction to information theory, first-order entropy; lossless methods such as Huffman coding, arithmetic coding, and dictionary methods; and lossy and transform coding including image, audio, and video formats. The emphasis in this course is on algorithmic understanding and applications rather than derivation from first principles. Not for graduate credit.
**Prerequisites:** MATH 210, COMP-SCI 303, or equivalent.

INFO-TEC 491 Internship Credits: 1-6
Students may participate in structured internships under the joint supervision of an employer and a faculty member. The student must carry out significant professional responsibilities that also have academic merit. The number of credit hours is based on the quality of the academic experience. Available for credit/no credit only, and students must be in good standing with a least 18 credit hours of CS/IT counting towards the degree.
**Prerequisites:** Departmental consent.