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Cybersecurity and Cyber Systems

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The Master of Science degree in Cybersecurity and Cyber Systems is an interdisciplinary program offered through the School of Computing and the School of Electrical, Computer, and Biomedical Engineering.

Master of Science (M.S.) in Cybersecurity and Cyber Systems

Admission

Applicants with a bachelors degree in Computer Science, Engineering, Physics, Mathematics, Information Systems or equivalent degrees will be admitted directly as long as their GPA satisfies Graduate School requirements. The M.S. in Cybersecurity and Cyber Systems requires 30 credit hours. Students can select an area of study in cybersecurity or in cyber systems. For applicants lacking the required specific background, we offer conditional admission status until completing prerequisite courses.

Admission to the M.S. in Cybersecurity and Cyber Systems program is based on the following factors: grade point average of 2.75 or higher on a scale of 4.0 on approximately the last 60 credit hours of undergraduate coursework, class ranking, and faculty recommendation letters. Although GRE scores are not required for admission, they are important to qualify for the High Achievers Tuition Rate. See also tuition.siuc.edu/highachievers2.html. The minimum TOEFL score requirement for international applicants is 550 (paper-based) or 80 (computer-based).

The program requires a nonrefundable $65 application fee that must be submitted with the application for admissions to the M.S. program in Cybersecurity and Cyber Systems. Students must apply online and pay this fee by credit card. Please address any correspondence to “Master of Science Program in Cybersecurity and Cyber Systems,” 1230 Lincoln Drive, Southern Illinois University Carbondale, Carbondale, Illinois 62901, Mailcode 6603 or Mailcode 4511. Inquiries can be addressed to cyberms@siu.edu. For telephone inquiries please call 618-536-2364 or 618-536-2327, and refer to the Master of Cybersecurity and Cyber Systems Program. The facsimile numbers are 618-453-7972 and 618-453-6044.

Retention

Any student whose cumulative grade point average falls below 3.0 on courses that count towards the degree will be placed on departmental academic probation. Any graduate student on academic probation whose grade point average remains below 3.0 on courses that count towards the degree for two consecutive semesters in which she or he is enrolled will be permanently suspended from the program, unless the department grants an exception.

Curriculum

The degree requires 3 courses from 3 key areas that will ascertain understanding of fundamentals and help build a solid foundation for the remainder of the program. These courses are listed below.

1. **Fundamentals in computer security.** This requirement will be completed by either CS 410 or ECE 434. Only one of these courses will count towards the degree.

2. **Fundamentals in systems programming.** This requirement will be completed by either CS 407 or ECE 536. Only one of these courses will count towards the degree.
3. **Fundamentals in network systems.** This requirement will be completed by either CS 440 or ECE 553. Only one of these courses will count towards the degree.

A student should then seek an area of study in either cybersecurity or cyber systems by selecting at least 5 elective courses in these areas. The lists of these courses are given below. A maximum of six credit hours from academic units outside the School of Computing and the School of Electrical, Computer, and Biomedical Engineering can be applied towards the degree.

In the area of cybersecurity, students must complete 4 courses in cybersecurity and 1 course in cyber systems. In the area of cyber systems, students must complete 4 courses in cyber systems and 1 course in cybersecurity. A fundamental area may be satisfied by a course that was taken prior to admission or a documented record of accomplishment in the subject matter content. In this case, the student must select an additional elective course either in cybersecurity or in cyber systems for each satisfied fundamental area. Students must take at least two CS/ECE five hundred level courses not cross listed to a four hundred level course. Students must take at least three ECE and at least three CS courses. Only three credit hours of ECE 592 or CS 598 can count towards the degree.

**MS Thesis option:** 6 credit hours of thesis in ECE or CS (ECE 599 or CS 599) may substitute for 6 credit hours in an area of study (cybersecurity or cyber systems).

The Master of Science degree program in Cybersecurity and Cyber Systems has an online option for the non-thesis track.

**List of cybersecurity courses for the MS degree:** CS 408, CS 409, CS 413, CS 415, ECE 418, ECE 517, ECE 518, ECE 519, CS 525, CS 531.

**List of cyber system courses for the MS degree:** ECE 417, ECE 419, CS 425, ECE 431, CS 441, ECE 475, ECE 512, ECE 528, ECE 536, CS 540, ECE 541.

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**CS404 - Autonomous Mobile Robots** 404-3 Autonomous Mobile Robots. This course is a comprehensive introduction to modern robotics with an emphasis on autonomous mobile robotics. Fundamentals of sensors and actuators as well as algorithms for top level control are discussed. Multi-robotics and human-robot interaction issues are explored. A group project is an integral part of this course. Prerequisite: CS 330 with a grade of C or better or graduate standing. CS fee: $125.

**CS406 - Basic Linux System Admin** 406-3 Basic Linux System Administration. This course will be an introduction to the administration of Linux systems, with emphasis on security for networked systems. Topics to be covered include: installation and configuration of Linux distributions, typical maintenance activities, and security measures for networked systems. Students will have access to lab machines for hands on practice. Prerequisite: CS 306 with a grade of C or better or graduate standing.

**CS407 - Adv Linux/UNIX Programming** 407-3 Advanced Linux/UNIX Programming. This course builds on the knowledge gained in CS 306, to prepare students to do advanced development on Linux/UNIX platforms. The topics studied are critical for achieving high performance in large-scale, high-load networked software systems. These topics include development techniques such as profiling, concurrent programming and synchronization, network programming for high-load servers, advanced I/O alternatives, and IPC such as shared memory. The course will involve the study of code from Open Source projects like Apache and Nginx. The focus will be on the C language, but other languages will also be considered. Students must complete a significant network software project. Prerequisites: CS 306 and CS 335, with grades of C or better, or graduate standing with C language and Linux system programming experience.

**CS408 - Applied Cryptography** 408-3 Applied Cryptography. This course is a comprehensive introduction to modern cryptography, with an emphasis on the application and implementation of various techniques for achieving message confidentiality, integrity, authentication and non-repudiation. Applications to Internet security and electronic commerce will be discussed. All background mathematics
will be covered in the course. Prerequisite: CS 330 with a grade of C or better and MATH 221 or graduate standing.

**CS409 - Ethical Hacking** 409-3 Ethical Hacking. This course will explore the various means that an intruder has available to gain access to computer resources. We will investigate weaknesses by discussing the theoretical background, and whenever possible, actually performing the attack. We will then discuss methods to prevent/reduce the vulnerabilities. This course is targeted specifically for Certified Ethical Hacking (CEH) exam candidates, matching the CEH exam objectives with the effective and popular Cert Guide method of study. Prerequisite: CS 202 with a grade of C or better or graduate standing.

**CS410 - Computer Security** 410-3 Computer Security. A broad overview of the principles, mechanisms, and implementations of computer security. Topics include cryptography, access control, software security and malicious code, trusted systems, network security and electronic commerce, audit and monitoring, risk management and disaster recovery, military security and information warfare, physical security, privacy and copyrights, and legal issues. Prerequisite: CS 306 with a grade of C or better or graduate standing.

**CS412 - Programming Distributed Apps** 412-3 Programming Distributed Applications. This course uses advanced features of the Java programming language to develop networked, distributed, and web-based applications. Topics covered include, but are not limited to, sockets, datagrams, the Java security model, threads, multi-tier architectures, Java RMI, Java database connectivity, and Java-based mobile agents. Prerequisite: CS 306 with a grade of C or better or graduate standing.

**CS413 - Digital Forensics** 413-3 Digital Forensics. Cybersecurity has become a ubiquitous concern well beyond finding solutions to post-mortem threat analysis. The course provides a broad overview of security objectives and will cover fundamentals in confidentiality, integrity, and availability. Lectures will offer a broad range of topics on digital forensics. Students will be trained for an investigation mindset. Contemporary tools and techniques for digital forensics and investigations are reviewed. Security for stationary and mobile platforms are foci of current course in both forensic and active modes. There will be multiple hands-on homework and laboratories as well as a practical project as an integral part of this course. Prerequisite: CS 330 with a grade of C or better or graduate standing.

**CS415 - Network Forensics** 415-3 Network Forensics. With the proliferation of wireless networks, security is at odds with privacy and integrity. The course provides a broad overview of security strategies for wireless networks. Topics will range from intrusion detection and network security protocols to collaborative computing. Contemporary tools and techniques for wireless network security are reviewed. A hands-on project will be an integral part of this course. Prerequisite: CS 330 with a grade of C or better or graduate standing.

**CS416 - Compiler Construction** 416-3 Compiler Construction. Introduction to compiler construction. Design of a simple complete compiler, including lexical analysis, syntactical analysis, type checking, and code generation. Prerequisite: CS 306 and 311 each with a grade of C or better or graduate standing.

**CS420 - Distributed Systems** 420-3 Distributed Systems. A top-down approach addressing the issues to be resolved in the design of distributed systems. Concepts and existing approaches are described using a variety of methods including case studies, abstract models, algorithms and implementation exercises. Prerequisite: CS 335 with a grade of C or better or graduate standing.

**CS425 - Prin Virtual & Cloud Computing** 425-3 Principles of Virtualization and Cloud Computing. Cloud Computing (CC) represents a recent major strategic shift in computing and Information Technology. This course explores fundamental principles, foundational technologies, architecture, design, and business values of CC. Understanding will be reinforced through multiple angles including: analysis of real world case studies, hands-on projects and in-depth study of research developments. Prerequisites: CS 330 with a grade of C or better or graduate standing.

**CS430 - Database Systems** 430-3 Database Systems. The course concentrates on the relational model, database design, and database programming. Topics include relational model, relational algebra, SQL, constraints and integrity, transaction support, concurrency control, database design, normalization,
backup, recovery, and security. A comprehensive product-like project is an integral part of the course. Prerequisite: CS 330 with a grade of C or better or graduate standing.

**CS431 - Cyber-Physical Systems** 431-3 Cyber-Physical Systems. The goal of this course is to introduce and develop an understanding of the computing and communication for Internet of Things as a subset of Cyber-Physical systems. Connectivity among devices in our daily lives such as WiFi-enabled thermostats, smart grids, and driverless cars is ushering in an era of sociality that transcends human social networks to machine to machine networks. Prerequisites: CS 330 with a grade of C or better or graduate standing.

**CS434 - Learning From Data** 434-3 Learning From Data. An introduction to classical machine learning theory and practical techniques. Topics to be covered include computational learning theory (VC theory), linear classification and regression models, SVMs and kernel methods, decision trees, the bias-variance tradeoff, overfitting, and regularization. Prerequisites: CS 330 with a grade of C or better or graduate standing.

**CS435 - Software Engineering** 435-3 Software Engineering. Principles, practices and methodology for development of large software systems. Object-oriented principles, design notations, design patterns and coping with changing requirements in the software process. Experiences with modern development tools and methodologies. A team project is an integral part of this course. Prerequisite: CS 330 with a grade of C or better or graduate standing; CS 306 with a grade of C or better recommended.

**CS436 - Artificial Intelligence I** 436-3 Artificial Intelligence I. Search and heuristics, problem reduction. Predicate calculus, automated theorem proving. Knowledge representation. Applications of artificial intelligence. Parallel processing in artificial intelligence. Prerequisite: CS 311 and 330 each with a grade of C or better or graduate standing.


**CS438 - Bioinformatics Algorithms** 438-3 Bioinformatics Algorithms. This course is an introductory course on bioinformatics algorithms and the computational ideas that have driven them. The course includes discussions of different techniques that can be used to solve a large number of practical problems in biology. Prerequisite: CS 330 with a grade of C or better or graduate standing.

**CS440 - Computer Networks** 440-3 Computer Networks. Design and analysis of computer communication networks. Topics to be covered include queuing systems, data transmission, data link protocols, topological design, routing, flow control, security and privacy, and network performance evaluation. Prerequisite: CS 330 with a grade of C or better or graduate standing; CS 306 recommended.

**CS441 - Mobile & Wireless Computing** 441-3 Mobile and Wireless Computing. Concepts of mobile and wireless systems are presented. These concepts include, but are not limited to, Routing and Medium Access for Mobile Ad hoc and Wireless Sensor Networks, Mobile IP, Wireless LAN and IEEE 802.11. Hands-on group lab experience is an integral component in the course. Prerequisite: CS 330 with a grade of C or better, or graduate standing or consent of the instructor.

**CS447 - Introduction to Graph Theory** 447-3 Introduction to Graph Theory. (Same as MATH 447) Graph theory is an area of mathematics which is fundamental to future problems such as computer security, parallel processing, the structure of the World Wide Web, traffic flow and scheduling problems. It also plays an increasingly important role within computer science. Topics include: trees, coverings, planarity, colorability, digraphs, depth-first and breadth-first searches. Prerequisite: MATH 349 with C or better.

**CS449 - Intro to Combinatorics** 449-3 Introduction to Combinatorics. (Same as MATH 449) This course will introduce the student to various basic topics in combinatorics that are widely used throughout applicable mathematics. Possible topics include: elementary counting techniques, pigeonhole principle, multinomial principle, inclusion and exclusion, recurrence relations, generating functions, partitions, designs, graphs, finite geometry, codes and cryptography. Prerequisite: MATH 349 with C or better.
CS451 - Theory of Computing 451-3 Theory of Computing. The fundamental concepts of the theory of computation including finite state acceptors, formal grammars, Turing machines, and recursive functions. The relationship between grammars and machines with emphasis on regular expressions and context-free languages. Prerequisite: CS 311 and 330 each with a grade of C or better or graduate standing.

CS455 - Adv Alg Design & Analysis 455-3 Advanced Algorithm Design and Analysis. An in-depth treatment of the design, analysis and complexity of algorithms with an emphasis on problem analysis and design techniques. Prerequisites: CS 330 with a grade of C or better or graduate standing.

CS471 - Optimization Techniques 471-3 Optimization Techniques. (Same as MATH 471) Introduction to algorithms for finding extreme values of nonlinear multivariable functions with or without constraints. Topics include: convex sets and functions; the arithmetic-geometric mean inequality; Taylor's theorem for multivariable functions; positive definite, negative definite, and indefinite matrices; iterative methods for unconstrained optimization. Prerequisite: MATH 221 and MATH 250 with C or better.

CS472 - Linear Programming 472-3 Linear Programming. (Same as MATH 472) Introduction to finding extreme values of linear functionals subject to linear constraints. Topics include: recognition, formulation, and solution of real problems via the simplex algorithm; development of the simplex algorithm; artificial variables; the dual problem and duality theorem; complementary slackness; sensitivity analysis; and selected applications of linear programming. Prerequisite: MATH 221 with C or better.

CS475 - Numerical Analysis I 475-3 Numerical Analysis I. (Same as MATH 475) Introduction to theory & techniques for computation with digital computers. Topics include: solution of nonlinear equations; interpolation & approximation; solution of systems of linear equations; numerical integration. Students will use MATLAB to study the numerical performance of the algorithms introduced in the course. Prerequisites: MATH 221 and MATH 250 with C or better.

CS480 - Computational Statistics II 480-3 Computational Statistics II. This course utilizes computational and graphical approaches to solve statistical problems. A comprehensive coverage on modern and classical methods of statistical computing will be given. Case studies in various disciplines such as science, engineering and education will be discussed. Various topics such as numerical integration and simulation, optimization and maximum likelihood estimation, density estimation and smoothing as well as re-sampling will be presented. Students will be able to create graphical and numerical display based on their data analysis results using R programming language. Prerequisite: MATH 250 and CS 306 or CS 330 with a grade of C or better or graduate standing.

CS484 - User Interface Dsgn & Devlpmt 484-3 User Interface Design and Development. Problems and processes in the design of highly usable systems. Understanding stakeholders, requirements, tasks, prototyping, evaluation, guidelines and design process and heuristics. Interactive software concepts and implementation considerations. A group project is an integral part of this course. Prerequisite: CS 306 with a grade of C or better or graduate standing.

CS485 - Computer Graphics 485-3 Computer Graphics. Principles and techniques of computer graphics. Interactive graphics software development using a modern graphics standard. Topics include: primitives, transforms, clipping, modeling, viewing, rendering, texture, animation and ray tracing. A group project is an integral part of this course. Prerequisite: CS 306 with a grade of C or better or graduate standing; MATH 150 and 221 are recommended.

CS487 - Software Game Development 487-3 Software Aspects of Game Development. This course focuses on software implementation and development aspects of game production including: software process, system architecture, frameworks, entity management and interaction design, game design, production and business issues as well as technical foundations in graphics modeling and rendering, collision detection, physics, artificial intelligence, and multiplayer techniques. Prerequisite: CS 330 with a grade of C or better or graduate standing.

CS491 - Special Topics 491-1 to 6 (1 to 3 per topic) Special Topics. Selected advanced topics from the various fields of computer science.

CS492 - Special Problems 492-1 to 6 (1 to 3 per semester) Special Problems. Individual projects involving independent work. Special approval needed from the instructor.
CS493 - Seminar 493-1 to 4 Seminar. Supervised study. Preparation and presentation of reports. Special approval needed from the instructor.


CS510 - Wireless and Network Security 510-3 Wireless and Network Security. Advanced security concepts of distributed systems and wireless networks are presented. Topics include IEEE 802.11 security, Wireless Encryption and Authentication, Key Management in Networks, Distributed Denial of Service Attacks, Routing Security, Intrusion Detection and Mobile Code Security. Prerequisite: CS 410 with a grade of C or better or consent of the instructor.

CS511 - Forml Spec Programmg Lang 511-3 Formal Specification of Programming Languages. A survey of modeling techniques and Meta languages for the formal specification of the syntax and semantics of high-level programming languages. Prerequisite: CS 311.

CS512 - Declarative Programming 512-3 Declarative Programming. An advanced level course on nonprocedural programming with emphasis on logic programming, pure functional programming, and the characteristics of the declarative style common to these two paradigms. Topics include logic programming, functional programming, implementation consideration for each along with current research topics in the areas. Prerequisite: CS 311.


CS515 - Computational Blockchain 515-3 Computational Blockchain. This course introduces fundamentals of modern blockchain-based systems as well as cryptocurrency applications. Topics for discussion include consensus and distributed computing, smart contracts, privacy and secrecy, and other relevant computational platforms. Non-currency applications of blockchains, and legal and social implications will be outlined. Students will be required to develop a term project. Prerequisites: CS 330 with grade of C or better or CS 410 or graduate standing.

CS516 - Advanced Compilers 516-3 Advanced Compilers. A continuation of 416 including advanced topics in lexical and syntax analysis, error recovery, semantic analysis, code optimization and compiler compilers. Prerequisite: CS 416.

CS520 - Adv Topic Parallel Distrb Comp 520-3 Advanced Topics in Parallel & Distributed Computing. An advanced treatment of parallel and distributed computing; review of hardware and software considerations for parallel computation; development and analysis of parallel algorithms (with particular attention to the communication and synchronization costs associated with parallel algorithms); effect of granularity on performance; a comparison of the parallel and distributed programming paradigms including a detailed study of the central features of each approach; software systems for distributed computing including exposure to one or more distributed programming environments; the direction of parallel computing as suggested by recent, high level parallel languages; parallelizing serial programs; parallelizing compilers; future directions of parallel and distributed computing systems. The course will include a student project. Prerequisite: CS 420.

CS525 - Security Issues Cloud Comp 525-3 Security Issues in Cloud Computing. This course offers a survey of security and privacy issues in Cloud Computing systems along with an overview of current
best practices and available technologies. Threat model as well as practical applications of secure Cloud Computing are explored. Prerequisite: CS 410 or graduate standing.

**CS530 - Advanced Database Systems** 530-3 Advanced Database Systems. A detailed treatment of advanced topics in database systems including, but not limited or restricted to, relational database theory, query optimization, recovery techniques, concurrency control, distributed database systems, security and integrity and database machines. Prerequisite: CS 430.

**CS531 - Security Cyber-Phys Systems** 531-3 Security in Cyber-Physical Systems. The course covers introductory topics in cyber-physical systems security. The goal is to expose students to fundamental security primitives specific to cyber-physical systems and to apply them to a broad range of current and future security challenges. Various tools and techniques used by hackers to compromise computer systems or otherwise interfere with normal operations are explored using tools that are unique to interacting with cyber-physical systems. Restricted to graduate standing or consent of the instructor.

**CS532 - Topics in Information Systems** 532-3 to 6 Topics in Information Systems. A detailed study of two or three topics relevant to information systems. Topics may include but are not limited to sorting, searching, information retrieval and automatic text processing, database security and encryption, distributed databases and data communication. Prerequisite: CS 430. Special approval needed from the instructor.

**CS533 - Data Mining/Big Data Analysis** 533-3 Data Mining and Big Data Analysis. This course provides a series of comprehensive and in-depth lectures on the core techniques in data mining and knowledge discovery; addresses the unique issues of big data; and discusses potential applications of data mining particularly on big data analysis. Major topics include: data preparation, association mining, classification (and prediction), clustering, characteristics and challenges of big data, and strategies of big data mining and analysis. Prerequisites: CS 330 and CS 430 with grades of C or better or consent of instructor.

**CS534 - Big Data Management/Analytics** 534-3 Big Data Management and Analytics. This course provides comprehensive and in-depth discussions of big data management and analytics. Main subjects include computation and programming models, management and analytics algorithms, and platforms/frameworks especially designed for big data. The objective of this course is to equip students with the ability to understand, use, and build big data management and analytics systems or tools. Prerequisites: CS 430 with a grade of C or better or graduate standing.

**CS536 - Artificial Intelligence II** 536-3 Artificial Intelligence II. Theorem proving, the Resolution Principle, strategies, and achievements. Program verification. Natural language processing. Other selected topics. Prerequisite: CS 436.

**CS537 - Adv Topics in Expert Systems** 537-3 Advanced Topics in Expert Systems. This course is designed to provide students with advanced topics in expert systems theory. Topics covered include: knowledge representation, methods of inference, reasoning under uncertainty, and inexact reasoning (fuzzy logic). A practical introduction to expert systems programming serves to reinforce and clarify the theoretical concepts. Prerequisite: CS 330 or consent of instructor.

**CS538 - Game Theory in Networks** 538-3 Game Theory in Networks. Game theoretic concepts apply whenever actions of several players are interdependent. This course will provide an introduction to classic game theory and strategic thinking including dominance, Nash equilibrium, and stability. Social choice, social learning, and online mechanism design are then discussed. We will examine how game theoretic concepts can be used in developing reasoning strategies, i.e., algorithms. Application of game theoretic framework to telecommunication and human networks is an integral part of this course. Restricted to graduate standing or consent of instructor.

**CS539 - Agents & Multiagent Systems** 539-3 Agents and Multiagent Systems. This is an advanced treatment of fundamental concepts in the design of intelligent autonomous agents and agent systems. Classic agent theories, architectures, algorithms, and languages are discussed. An agent-based project is an integral part of this course. Restricted to graduate standing or consent of instructor.

**CS540 - Adv Comp Networks** 540-3 Advanced Computer Networks. Topics include routing protocols used in internet; data compression techniques; telecommunication systems - its services, architecture and protocols; high speed networks; routing protocols in mobile ad-hoc networks; and a detailed performance
analysis of different window flow control and congestion control mechanisms using queuing theory. Prerequisite: CS 440 with a grade of C or better, or consent of the instructor.

**CS553 - Formal Languages & Automata** 553-3 Formal Languages and Automata. The Chomsky hierarchy of formal grammars and the corresponding classes of automata. Turing machines and basic concepts of computability. Recursive and recursively enumerable languages. Closure properties. Undecidable problems about Turing machines and context-free languages. Deterministic context-free languages and the construction of LR parsers. Prerequisite: CS 451.


**CS572 - Adv Topics in Num Analysis** 572-1 to 12 Advanced Topics in Numerical Analysis. (Same as MATH 572) Selected advanced topics in Numerical Analysis chosen from such areas as: approximation theory; spline theory; special functions; wavelets; numerical solution of initial value problems; numerical solution of boundary value problems; numerical linear algebra; numerical methods of optimization; and functional analytic methods. Special approval needed from the instructor.


**CS586 - Pattern Recognition** 586-3 Pattern Recognition. An introduction to the area of pattern recognition and data science. This course will cover basic and advanced theories, algorithms, and practical solutions of statistical pattern recognition. It covers bayesian learning, parametric and non-parametric learning, data clustering, component analysis, boosting techniques, sequential data, reinforcement learning, and deep learning with neural networks.

**CS590 - Readings** 590-1 to 6 Readings. Supervised readings in selected subjects. Graded S/U only. Special approval needed from the instructor.

**CS591 - Special Topics** 591-1 to 9 (1 to 3 per topic) Special Topics. Selected advanced topics from the various fields of computer science. Repeatable on different topics toward degree credit.

**CS593 - Seminar** 593-1 to 4 Seminar. Preparation and presentation of reports. Graded S/U only. Special approval needed from the instructor.

**CS598 - Graduate Project** 598-3 to 9 Graduate Project. A practical exercise in the design, implementation, documentation and deployment of a project. A project may be completed through internship, work/study, or a supervised project. For Ph.D. students only, an internship could include face-to-face or online teaching.

**CS599 - Thesis** 599-3 to 9 Thesis. Special approval needed from the instructor.

**CS600 - Doctoral Dissertation** 600-1 to 24 (1 to 9 per semester) Doctoral Dissertation. Dissertation research. Hours and credit to be arranged by the student's academic advisor. Graded S/U only. Restricted to admission to Ph.D. in computer science program.

**CS601 - Continuing Enrollment** 601-1 per semester Continuing Enrollment. For those graduate students who have not finished their degree programs and who are in the process of working on their dissertation, thesis, or graduate project. The student must have completed a minimum of 24 hours of dissertation research, or the minimum thesis or graduate project hours before being eligible to register for this course. Concurrent enrollment in any other course is not permitted. Graded S/U or DEF only.

evaluation. Process validation and verification. SysML graphical modeling language. Prerequisites: ECE 315 and ECE 327 with grade of C or better.


**ECE429 - Computer Systems Architecture** 429-3 Computer Systems Architecture. (Same as ECE 529) Principles of performance evaluation, processor microarchitecture, instruction-level parallelism, static and dynamic pipeline considerations. Superscalar processors. Multiprocessor systems. Memory hierarchy design, cache design. Mutual exclusion and synchronization mechanisms. Prerequisite: ECE 329 with a grade of C or better.


**ECE459 - MEMS and Micro-Engineering** 459-3 MEMS and Micro-Engineering. Introduction to micro-electro-mechanical systems (MEMS), manufacturing techniques, microsensors, microactuators, microelectronics and micro-controllers. Lecture and laboratory. Prerequisite: ECE 315 and ECE 356.

**ECE468B - Digital Signal Processing** 468B-3 Digital Signal Processing. Discrete-time signals and systems: z-transform; discrete Fourier transform, fast Fourier transform algorithms; digital filter design; digital filter realizations. Lecture and laboratory. Restricted to graduate standing. Lab fee: $20 to help defray cost of software licenses.

**ECE471 - Wireless Communications** 471-3 Wireless Communication Systems. This course covers fundamentals of wireless communication systems. Topics include wireless system architectures, channel modeling, introduction to cellular systems, digital modulation and multiple-access techniques, introduction to multi-antenna techniques, performance analysis, wireless physical layer security, future trends in wireless communications. Prerequisites: ECE 315 and ECE 355 or consent of instructor. Project-based fee: $20 to help defray cost of software licenses.


**ECE486 - Clean Electric Energy** 486-3 Clean Electric Energy. History and future of energy resources and their use as a component of electrical systems. Fossil fuels and renewable energy sources. Environmental and economical impacts of various energy sources. Electric energy generating plants and distributed generation. Design of hybrid renewable energy systems. Prerequisite: ECE 385 with a grade of C or better.

**ECE487 - Power Systems Analysis** 487-3 Power Systems Analysis. Modeling and analysis of electric power systems. Topics covered: ac power, generators, power transformers, transmission line parameters
and steady state operation, computation of power flows. The course uses power system analysis software. Lecture. Prerequisite: ECE 385 with a minimum grade of C.

ECE511 - Emb Sys HW/SW Codesign 511-3 Hardware/Software Co-design of Embedded Systems. This course will present state-of-the-art concepts and techniques for the design of embedded systems consisting of hardware and software components. Discussed topics include operating system structure, cross-compilation configurations, embedded system design, hardware/software co-design, embedded system specification and modeling, optimization algorithm for hardware/software co-design, system-level architectures for embedded systems etc. Restricted to graduate standing.

ECE512 - Wireless Networks 512-3 Wireless Networks. (Same as ECE 412) Compared to infrastructure based wireless communication systems, ad hoc wireless networks present several unique advantages. Thus, it has been widely studied as an important wireless communication paradigm. This graduate level course first introduces several widely adopted wireless communication technologies and then presents the concept, structure, and principles of ad hoc wireless networks. The course also introduces the details of several popular ad hoc wireless networks including mobile ad hoc networks, delay tolerant networks, wireless sensor networks, and connected vehicle networks. Novel applications in those networks will also be introduced. The course work will include paper and literature review, presentations, assignments, and a project that will enable students to be familiar with ad hoc wireless networks. NS2 will be used for student project in this course. Students can gain experience on NS2. Project-based fee: $10 to help defray cost of equipment.


ECE515 - Three Dimension Integrtn Systs 515-3 Three Dimensional Integration Systems. This course introduces the design of three dimensional VLSI integration systems, including through-silicon-via (TSV) process, characterization and modeling, 3D IC systems design, mixed signal simulation, data management, testing, process, variation, thermal and reliability challenges, as well as review of 3D system design examples. Laboratory experience in design tools (Cadence Virtuoso and Liberate, AMS simulator). Prerequisite: ECE 345 and ECE 423 with a grade of C or better. Restricted to enrollment in ECE program.

ECE516 - Implement VLSI Systs w/HDL 516-3 Implementation of VLSI Systems with HDL. (Same as ECE 426) This course is dedicated for advanced Digital VLSI architecture and system implementation for high performance and low power digital signal processing applications. Application-specific processors and architectures to support real time processing of signal processing systems will be studied. Hands-on experience of using state-of-the-art CAD tools on designing such kind of VLSI architecture and systems. Upon completion of this course, students will entail large HDL-based implementation of a complete VLSI system. Prerequisite: ECE 327 with a grade of C or better. Project-based fee: $35 to help defray cost of software licenses and equipment.

ECE517 - Modern Cryptography 517-3 Modern Cryptography. Probability and basic number theory, block ciphers and key-recovery security, pseudorandom functions, symmetric encryption, hash functions, message authentication codes, authenticated encryption, asymmetric encryption, digital Signatures, key distribution, lattice-based cryptography, identity-based encryption, zero-knowledge e techniques, introduction to quantum cryptography.

Watermarking, Hardware metering. Side channel attacks including fault injection and power analysis. Types of hardware Trojan attacks (forms and sizes). Detection of hardware Trojans. Hardware tampering and obfuscation. Countermeasures against hardware attacks and hardware authentication. Counterfeit circuits: detection and avoidance. Trust issues in FPGAs. JTAG security and trust. SoC security requirements and secure design. Prerequisite: ECE 418 or graduate standing.


ECE520 - VLSI Design & Test 520-3 VLSI Design and Test Automation. Principles of the automated synthesis, verification, testing and layout of Very Large Scale Integrated (VLSI) circuits concentrating on the CMOS technology. Resource allocation and scheduling in high-level synthesis. Automation of the logic synthesis for combinational and sequential logic. The physical design automation cycle and CMOS technology considerations. Fault modeling and testing. Timing analysis. Laboratory experience using commercial tools for synthesis and layout. Students who completed ECE 425 can't take ECE 520. They are similar. Prerequisite: ECE 327 with a C- or better or enrollment in ECE graduate programs. Project-based fee: $30 to help defray cost of software licenses and equipment.


ECE523 - Low Power VLSI Design 523-3 Low Power VLSI Design. Source of power dissipation, technology impact on power dissipation, low power circuit techniques, energy recovery, synthesis of low power circuits, low power components. Prerequisite: ECE 423 or ECE 513 with a minimum grade of C or consent of instructor. Restricted to enrollment in ECE program. Project-based fee: $35 to help defray cost of software licenses and equipment.

ECE524 - Synth/Verif Digital Circuits 524-3 Synthesis and Verification of Digital Circuits. Binary decision diagrams, finite state machines and finite automata. Design automation concepts in logic level synthesis, optimization and verification for combinational as well as sequential logic. Technology mapping. Prerequisite: ECE 425 or ECE 520 with a minimum grade of C or consent of instructor. Restricted to enrollment in ECE program. Project-based fee: $35 to help defray cost of software licenses and equipment.

ECE525 - Adv Physical Design Automation 525-3 Advances in Physical Design Automation. Advances in the automation of VLSI layouts with emphasis on recent developments in deep submicron, FPGA and MCM technologies. Floor planning, placement, routing objectives in high performance designs using deep submicron technology. Timing analysis in the presence of crosstalk. FPGA architectures and design with dynamically reconfigurable FPGAs. Physical design automation for MCMs. Prerequisite: ECE 425 or ECE 520 with a minimum grade of C or consent of instructor. Restricted to enrollment in ECE program. Project-based fee: $35 to help defray cost of software licenses and equipment.

ECE526 - Network Process Syst Design 526-3 Network Processing Systems Design. Protocol processing, packet processing algorithms, classification and forwarding, queuing theory, switching fabrics, network processors, network systems design tradeoffs. Prerequisite: ECE 422 and ECE 429 or consent of the instructor. Restricted to enrollment in ECE program.

ECE527 - Integ Interconnection Networks 527-3 Integrated Interconnection Networks. Importance of interconnection networks and networks-on-chip (NOCs). Specifications and constraints. Topology,
routing, flow control, deadlock, livelock, arbitration, allocation, performance analysis, simulation.
Restricted to enrollment in ECE program.

**ECE528 - Programmable ASIC Design** 528-3 Programmable ASIC Design. (Same as ECE 428)
Principle and practice of designing and implementing Application-Specific Integrated Circuits (ASIC).
Field Programmable Gate Arrays (FPGA). Timing analysis, timing closure and managing difference clock
domains in ASIC design. Complex arithmetic circuits. Digital signal processing (DSP) circuits. FPGA
microprocessors. Project-based fee: $50 to help defray cost of equipment and consumable items.

**ECE529 - Computer Systems Architecture** 529-3 Computer Systems Architecture. (Same as ECE 429)
Principles of performance evaluation, processor microarchitecture, instruction-level parallelism, static and
dynamic pipeline considerations. Superscalar processors. Multiprocessor systems. Memory hierarchy
design, cache design. Mutual exclusion and synchronization mechanisms. Restricted to enrollment in
ECE program.

**ECE530 - Engineering Data Acquisition** 530-3 Engineering Data Acquisition. (Same as ENGR 530)
Theory of data acquisition and measurement systems. Criteria for selection of data acquisition hardware
and software, instruments, sensors and other components of scientific and engineering experimentation.
Methods for sampled data acquisition, signal conditioning, interpretation, analysis and error estimation.
Restricted to enrollment in ECE program. Project-based fee: $60 to help defray cost of software licenses
and equipment.

**ECE531 - Mixed-Signal VLSI Design** 531-3 Mixed-Signal VLSI Design. Analysis and design of mixed-
signal integrated circuits. Digital to analog converter (DAC). Analog to digital converter (ADC). Sigma-
delta data converters. Performance analysis of signal chains containing both analog and digital signal
processing functions. Prerequisite: ECE 446 with a minimum grade of C. Restricted enrollment in ECE
program. Project-based fee: $60 to help defray cost of software licenses and equipment.

**ECE532 - Parallel Programming** 532-3 Programming Parallel Processors. (Same as ECE 432) Multi-
core architecture, threads, thread execution models, thread priority and scheduling, concurrency, multi-
threaded programming models, synchronization, performance measurement and local balance, software
tools for multi-threaded programming. Restricted to ECE students or consent of advisor. Project-based
fee: $20 to help defray cost of equipment.

**ECE533 - Speech Processing** 533-3 Speech Processing. (Same as BME 533, ECE 474) Fundamentals
of speech production system, signal analysis of speech, speech coding, linear prediction analysis, speech
synthesizing, and speech recognition algorithms. Prerequisite: MATH 250, ECE 355 with grades of C or
better or consent of instructor.

**ECE534 - Biomedical Signal Analysis** 534-3 Biomedical Signal Analysis. (Same as ECE 498, BME 536)
The nature of biomedical signals. Electricity in living tissue. Biomedical signal processing and modeling.
Modeling and simulation of biomedical systems. Prerequisite: MATH 250, ECE 355 with a grade of C or
better or consent of instructor. Project-based fee: $20 to help defray cost of software licenses.

**ECE535 - CMOS RF-IC Design** 535-3 CMOS Radio-Frequency Integrated Circuit Design. (Same as ECE
440) Introduction of RF IC, passive RLC Networks, passive IC components. MOS Transistors, distributed
systems, Smith Chart and S-Parameters, introduction to Band-width estimation, biasing and voltage
reference, basic High Frequency Amplifiers, introduction to: noise in RF IC, Low Noise Amplifiers, Power
Amplifiers, Phase-Locked Loops and Oscillators. Lecture and laboratory. Lab fee: $35 to defray the cost
of software licenses and equipment.

**ECE536 - Embedded Systems** 536-3 Embedded Systems Programming. Advanced software concepts
and techniques to develop complex software projects on embedded systems. Concepts and techniques
include system calls, structure of operating systems, advanced dynamic memory management, cross-
compilation, scheduling techniques and resource management.

**ECE537 - Integrated Photonics** 537-3 Integrated Photonics. Fundamentals of electromagnetic theory,
waveguides, photonic structures including photonic crystals and integrated micro-ring resonator,
umerical simulations of photonic integrated circuits using the beam propagation method, finite-difference
time-domain method, rate equations, and fabrication processes. Prerequisite: ECE 441 or consent of instructor. Restricted to enrollment in ECE program.

**ECE538 - Medical Instrumentation** 538-3 Medical Instrumentation: Application and Design. (Same as ECE 438 and BME 538) This course introduces basic concept of medical instrumentation, basic sensors and principles, amplifiers, biopotential, and applications to biopotential measurements. The course will focus on application and design of medical instrumentations. The course also will introduce biosensor, biomedical signal processing, and other related topics. Prerequisite: MATH 250 with a grade of C or better, or consent of instructor. Project-based fee: $45 to help defray cost of software licenses and equipment.

**ECE539 - Diagnostic Ultrasound** 539-3 Diagnostic Ultrasound. (Same as ECE 494 and BME 541) Diagnostic ultrasound is an ultrasound-based biomedical imaging technique used to visualize muscles, tissue, and many internal organs, to capture their size, structure and any pathological lesions. This course is an introduction to the principles and applications of biomedical ultrasound. This course will focus on fundamentals of acoustic theory, principles of ultrasonic detection and imaging, design and use of currently available tools for performance evaluation of diagnostic devices, and biological effects of ultrasound. Prerequisite: MATH 250 with a grade of C or better, or consent of instructor. Project-based fee: $30 to help defray cost of equipment and consumables.

**ECE540 - CMOS RF-IC Design II** 540-3 CMOS Radio-Frequency Integrated Circuit Design II. High frequency amplifier design techniques, noise in RF and CMOS low noise amplifiers (LNA), mixers, oscillators, PLLs, frequency synthesizers, power amplifiers, an overview of wireless architectures. Prerequisite: ECE 440 or ECE 535 or equivalent. Lab fee: $50 to defray the cost of software licenses and equipment.


**ECE542 - Photonics I** 542-3 Photonics I. (Same as ECE 441) Ray optics, wave optics, beam optics, polarization of light, statistical optics, photons and atoms. Prerequisite: ECE 375 with a grade of C or better. Project-based fee: $50 to help defray cost of equipment and consumables.


**ECE544 - Photonics II** 544-3 Photonics II. (Same as ECE 448) Fourier optics, fiber optics, electro-optics, nonlinear optical media, acousto-optics, photonic switching, optical and interconnections and optical storage. Prerequisite: ECE 441 or consent of instructor. Project-based fee: $80 to help defray cost of software licenses.


ECE549 - Fiber Optic Communications 549-3 Fiber Optic Communications. Fundamentals of step index and graded index fiber waveguides using geometrical optics and Maxwell's equations. Other topics include design criteria, practical coupling techniques, discussion of optical sources and detectors used in light-wave communications, system examples, characterization and measurement techniques. Prerequisite: ECE 447 or ECE 448 or consent of instructor. Restricted to enrollment in ECE program.

ECE550 - Nanoscale VLSI Devices 550-3 Nanoscale VLSI Devices. Review of fundamental principles of semiconductor devices. NanoTransistor: Charge-based devices-MOSFETs, non-ideal, atomistic, and quantum effects in nanoscale MOSFETs, charge-coupled devices. Advanced MOSFETs: FinFETs, SOI, SiGe and III-Vs, carbon nanotubes, graphene and 2-D semiconductors, nanowires. High electron mobility transistors (HEMTs), HBTs, and power MOSFETs. Compact and SPICE models for MOS devices. VLSI interconnects, parasitic elements, 3-D integration and reliability issues. Non-charge based devices-tunnel FETs, spin-based devices. NanoMemory: EEPROM and Flash, phase change memory, memristors, magnetic and ferroelectric, spin-torque devices, DRAM and ZRAM cells. TCAD simulation of semiconductor devices. Prerequisite: ECE 447 or ECE 423 or ECE 446 or PHYS 425 or PHYS 430 with C or better or instructor consent. Project-based fee: $25 to help defray cost of software licenses.

ECE551 - Prob and Stochastic Processes 551-3 Probability and Stochastic Processes for Engineers. (Same as ENGR 521) Axioms of probability, random variables and vectors, joint distributions, correlation, conditional statistics, sequences of random variables, stochastic convergence, central limit theorem, stochastic processes, stationarity, ergodicity, spectral analysis, and Markov processes. Restricted to graduate student status. Restricted to enrollment in ECE program. Project-based fee: $20 to help defray cost of software licenses.

ECE552 - Signal Detection & Estimation 552-3 Signal Detection and Estimation. Estimation theory: parameter estimation, minimum variance unbiased estimators, sufficient statistics, Cramer-Rao lower bound, best linear unbiased estimators, maximum likelihood estimators, least squares, Bayesian estimation, maximum a posteriori estimators, minimum mean square error estimators, linear minimum mean square error estimators, Wiener filtering. Detection theory: hypothesis testing, likelihood ratios, Neyman-Pearson detection, Bayesian hypothesis testing, matched filtering, multiple hypothesis testing, sequential detection, composite hypothesis testing, uniformly most powerful tests, generalized likelihood-ratio tests. Prerequisite: ECE 551 or consent of instructor. Restricted to enrollment in ECE program.

networking and QoS. Restricted to enrollment in ECE program. Project-based fee: $10 to help defray cost of equipment.

**ECE554 - Broadband Wireless Comm** 554-3 Broadband Wireless Communications. This course covers fundamentals of broadband wireless communications. Topics include concepts of space-time propagation, probabilistic modeling of space-time channel and signal models, multi-antenna (MIMO) systems, space-time coding, spatial diversity, spatial multiplexing, space-time receivers, orthogonal frequency division multiplexing (OFDM), MIMO OFDM, multi-user MIMO, performance analysis and trade-offs in MIMO channels, concepts of spread spectrum systems, frequency hopping, and direct sequence systems. Restricted to enrollment in ECE program or consent of instructor.

**ECE555 - Intro to Info Theory** 555-3 Introduction to Information Theory and Channel Coding. (Same as ECE 476) Entropy and Mutual Information. Channel Capacity. Gaussian Channel. Linear Block Codes. Convolutional Codes. Advance Channel Coding Techniques. Restricted to enrollment in ECE program.

**ECE556 - Digital Communications** 556-3 Digital Communications. Digital communication signals and systems characterization. Deterministic receiver design. Probabilistic receiver design. Error control coding. Communication over band limited channels. Prerequisite: ECE 551 or consent of the instructor. Restricted to enrollment in ECE program.


**ECE558 - Digital Image Processing I** 558-3 Digital Image Processing I. (Same as ECE 458) Basic concepts, scope and examples of digital image processing, digital image fundamentals, image sampling and quantization, an image model, relationship between pixels, enhancement in the spatial domain, enhancement in the frequency domain, image segmentation, basics of color image processing. Special approval needed from the instructor. Restricted to enrollment in ECE program.

**ECE560 - VLSI Characterization** 560-3 VLSI Material and Device Characterization. Materials for modern VLSI: semiconductor crystals, tubular and monolayer materials, organic materials, heterostructures, wafers and notations. Nanoscale fabrication processes: IC production flow, selective doping, nanolithography, etching, contacts and interconnects, spontaneous formation and ordering of nanostructures, fabrication of MEMS/NEMS systems, IC assembly and packaging. VLSI device characterization: electrical CV and IV profiling, defect characterization using DLTS, carrier mobility and lifetime measurements, optical microscopy and spectroscopy, particle beam and X-ray techniques. Reliability of devices and ICs: harsh environments, hot carriers, NBTI, electromigration, electrostatic discharge, IC power dissipation and cooling. Prerequisite: ECE 447 or ECE 423 or PHYS 425 with a grade of C or better or instructor consent. Lab fee: $35 to help defray the cost of software licenses.

**ECE561 - Mechatronics/Embedded Control** 561-3 Mechatronics and Embedded Control. (Same as ECE 456) Components of mechatronics systems, mathematical modeling, system identification, numerical tools for design and analysis, single-loop controller design, embedded systems, data acquisition and signal conditioning, sensors, actuators, networked control. This course includes lab session. Lab fee: $35 to help defray the cost of software licenses.

**ECE562 - Microwave Engineering I** 562-3 Microwave Engineering I. (Same as ECE 479) Electromagnetic theory, analysis, design, fabrication, measurement and CAD applied to passive networks at microwave frequencies. Topics include: Transmission lines, Waveguides, Impedance matching, Tuning, Resonators, Scattering parameters, the Smith Chart. Lecture and Laboratory. Prerequisite: ECE 375 or equivalent. Restricted to enrollment in ECE program. Project-based fee: $100 to help defray cost of software licenses.

ECE565 - Nonlinear Control Systems 565-3 Nonlinear Control Systems. Analysis and design of nonlinear dynamical systems. Topics include: nonlinear differential equations, stability, Lyapunov stability analysis, stability of perturbed systems, linearization, and central manifold theorem. Stabilization, feedback linearization, and controller design methods such as backstepping and sliding mode control.

ECE566 - Linear Systems Theory 566-3 Linear Systems Theory. Introduction to the structure and analysis of linear dynamical systems in time domain. Linear algebra review, solutions of linear differential equations, state-space representations, state transition matrix, and time varying systems. Introduction to fundamental mathematics of linear spaces and linear operator theory. Structural properties of linear systems such as controllability, observability, and stability. Design and synthesis of controllers and state observers for linear systems. Linear quadratic regulatory theory and Kalman filter.

ECE567 - Modern Biomedical Imaging 567-3 Modern Biomedical Imaging. (Same as ECE 467 and BME 532) Modern biomedical imaging. Diagnostic x-ray projection imaging. Tomographic imaging. Ultrasound imaging and therapy. Magnetic resonance imaging (MRI). Signal and noise characteristics. Image quality evaluation. Three-dimensional image reconstruction algorithms. Prerequisite: ECE 355 or consent of instructor. Restricted to enrollment in ECE program. Project-based fee: $30 to help defray cost of software licenses and equipment.


ECE569 - Biomedical Instrumentation 569-3 Biomedical Instrumentation. (Same as BME 538) Basic concept of Medical instrumentation, basic sensors and principles, amplifiers, biopotential electrodes, blood pressure and sound, measurement of respiratory system, chemical biosensors, Cellular measurements, Nervous system measurements, magnetic resonance imaging. Prerequisites: PHSL 410A or CHEM 444 or consent of instructor. Restricted to enrollment in ECE program. Lab fee: $45 to help defray cost of software licenses and equipment.

ECE570 - Communication Systems 570-3 Principles of Communication Systems. This course covers principles of communication systems. Topics include representation of signals and systems, amplitude modulation, angle modulation, probability theory and random processes for communication system designs, transition from analog to digital and pulse code/delta modulation, baseband digital transmission, digital band-pass transmission techniques, introduction to information theory and coding, wireless channel modeling, cellular systems and performance analysis. Lectures and laboratory projects. Prerequisites: ECE 315 and ECE 355 or consent of instructor. Students having passed ECE 478 are not eligible to enroll.

ECE571 - Advanced Wireless Comm 571-3 Advanced Wireless Communication. This course covers advanced topics in wireless communications. Topics include wireless system architectures, wireless channel modeling, cellular systems and co-channel interference, advanced digital modulation and multiple-access techniques, massive MIMO, mm-wave communications, performance analysis, radio resource allocation and optimization, wireless physical layer security, enabling technologies for 5G. Restricted to enrollment in ECE program or consent of instructor. Project-based fee: $20 to help defray cost of software licenses.

ECE572 - Neural Networks 572-3 Neural Networks. Anatomy and physiology of the cerebral cortex. Feed-forward Networks, Linear Associator, Multilayer Perceptrons. Feedback Networks, Hopfield Networks, ART. Applications to pattern recognition, robotics and speech processing. Optical and
electronic implementations. Prerequisite: MATH 305 or consent of instructor. Restricted to enrollment in ECE program.

**ECE573 - Fields and Waves II** 573-3 Field and Waves II. Time-harmonic electromagnetic fields in dielectric and lossy media, transmission lines, antennas and resonators. Techniques include duality, image theory, reciprocity and integral equations. Boundary value problems solved for several frequently encountered symmetries. Prerequisite: ECE 477. Restricted to enrollment in ECE program.

**ECE574 - Nonlinear Optics** 574-3 Nonlinear Optics. Coupled-mode-analysis applied to nonlinear wave interactions, harmonic generation, parametric amplification, backward wave amplifiers, backward oscillation in laser systems, phase conjugation and multiple-wave mixing systems, Pockel and Kerr effects, and electro-optical modulations in optical communication systems. Prerequisite: ECE 375 or consent of instructor. Restricted to enrollment in ECE program.

**ECE575 - Antennas I** 575-3 Antennas I. (Same as ECE 472) Analysis, design, fabrication, measurement and CAD applied to basic antenna types. Fundamental parameters. Friis transmission equation. Impedance and pattern measurements. Resonant microstrip and wire antennas. Arrays and line sources. Lecture and laboratory. Prerequisite: ECE 375 or equivalent. Restricted to enrollment in ECE program. Project-based fee: $120 to help defray cost of software licenses.

**ECE576 - Numeric Electromagnetics** 576-3 Numerical Electromagnetics. Numerical solution of electromagnetic problems by methods that include finite element, integral equation, moment, spectral domain and finite difference. Examination of electromagnetic problems and their solutions in current literature. Prerequisite: ECE 573. Restricted to enrollment in ECE program.

**ECE577 - Antennas II** 577-3 Antennas II. Analysis, design and CAD of antennas. Numerical methods. Broadband, traveling-wave, frequency independent, electrically-small, aperture and microstrip antenna types. Prerequisite: ECE 472. Restricted to enrollment in ECE program.

**ECE578 - DIP II** 578-3 Digital Image Processing II. Full-color image processing, image noise and degradation models, image restoration, inverse filtering, Wiener filtering, geometric transformations, image compression models, error-free compression, lossy compression, compression standards, dilation and erosion, opening and closing operations, morphological filtering, boundary descriptors, regional descriptors, principal components, vision-based pattern recognition. Prerequisite: ECE 558. Restricted to enrollment in ECE program.

**ECE579 - Microwave Engineering II** 579-3 Microwave Engineering II. Analysis and design of passive and active devices at microwave frequencies. Topics include: power dividers, couplers, filters, ferrite devices, noise, noise effects in detectors, mixers, modulators, amplifier and oscillator design, and an introduction to microwave systems. Prerequisite: ECE 479. Restricted to enrollment in ECE program.

**ECE580 - Seminar** 580-1 Seminar. Study and formal presentation by students of selected research in electrical and computer engineering. Restricted to students in the graduate program in Electrical and Computer Engineering. Special approval needed from the instructor.

**ECE581 - Wind & Solar Power Systems** 581-3 Wind and Solar Energy Power Systems. (Same as ECE 481) The course introduces students to wind and solar energy power systems. Planning of wind generation; and operation of wind generators, mechanical and electrical design, power conditioning, control and protection. Planning, operation and design of electric solar plants; power conditioning, control and protection.

**ECE582 - Power Converter Design** 582-3 Power Converter Design and Control. (Same as ECE 482) This course covers all the steps required for designing an actual power converter or electric drive system. The power stage design considerations, gate drive circuits, isolated high voltage/current measuring circuits, and application of a Texas Instrument Digital Signal Processor (DSP) for implementing different control schemes are discussed in detail. A brief introduction about the digital control theory and implementation of digital controller transfer functions using the DSP are provided as well. Project-based fee: $65 to help defray cost of software licenses and equipment.

**ECE583 - Electric Drive Systems** 583-3 Electric Drive Systems. (Same as ECE 483) Course content is roughly 1/3 power electronics, 1/3 applied control and 1/3 electric machinery and focuses on analysis,
simulation, and control design of electric drive based speed, torque, and position control systems. Advanced topics depending on the semester are taught. Project-based fee: $65 to help defray cost of software licenses and equipment.

ECE584 - Electric and Hybrid Vehicles 584-3 Electric and Hybrid Vehicles. (Same as ECE 484) This course covers an entire range of topics related to analysis, design, control, and optimization of electric, hybrid, and plug-in hybrid power trains including automotive applications of adjustable speed motor drives, energy storage systems, and advanced power converters. Restricted to enrollment in ECE program or consent of the instructor. Lab fee: $65 to help defray cost of software licenses and equipment.


ECE586 - Power System Methods 586-3 Computational Methods in Power Systems. The course covers advanced methods for the computation and analysis of power systems. Topics: circuit graph theory and network matrices, computation of electromagnetic transients, computation of power flows and faults, computation of system stability, stochastic methods in power systems, load forecasting, state estimation, unit dispatch. The course uses power system software. Lecture. Restricted to enrollment in the ECE program.

ECE587 - Modern Power Systems Op 587-3 Modern Power Systems Operation. This course provides students with a comprehensive picture of the techniques used in modern power systems operation. The course introduces central “terminal” characteristics for thermal and hydroelectric power generation systems, along with new optimization techniques for tackling “real-world” power systems operating problems. The topics include: analysis of different bidding strategies in competitive electricity markets, prediction of load and price, analysis of power systems security, different methods of optimal power flow, analysis of power systems uncertainty and reliability, economic dispatch, and unit commitment analysis. Project-based fee: $65 to help defray cost of software licenses and equipment.

ECE588 - Power System Engineering 588-3 Power System Engineering. (Same as ECE 488) The course covers topics involving the design and operation of a power system. Topics: symmetrical and unsymmetrical power system faults, power system protection design, transient stability of power generators, power system economic operation, power system control, transient operation of transmission lines. The course uses power system software. Lecture.


ECE592 - Special Investigations 592-1 to 3 Special Investigations in Electrical Engineering. Individual advanced projects and problems selected by student or instructor. Restricted to graduate standing. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593A - Adv Topics ECE Antennas/Propag 593A-1-3 Advanced Topics in Electrical Engineering-Antennas and Propagation. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593B - Adv Topics ECE-ASIC Design 593B-1-3 Advanced Topics in Electrical Engineering-ASIC Design. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593C - Adv Topics ECE-Communications 593C-1-3 Advanced Topics in Electrical Engineering-Communications. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.
ECE593D - Adv Topics ECE-Comp Architect 593D-1-3 Advanced Topics in Electrical Engineering-Computer Architecture. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593E - Adv Topics ECE-Control Systems 593E-1-3 Advanced Topics in Electrical Engineering-Control Systems. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593F - Adv Topics ECE-Design Automatn 593F-1-3 Advanced Topics in Electrical Engineering-Design Automation. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593G - Adv Topics ECE-Digital Design 593G-1-3 Advanced Topics in Electrical Engineering-Digital Design. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593H - Adv Topics-Digital Test/Verify 593H-1-3 Advanced Topics in Electrical Engineering-Digital Testing and Verification. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593I - Adv Topics ECE-Elec Flds/Waves 593I-1-3 Advanced Topics in Electrical Engineering-Electromagnetic Fields and Waves. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593J - Adv Topics ECE-Embedded System 593J-1-3 Advanced Topics in Electrical Engineering-Embedded Systems. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593K - Adv Topics ECE-Medical Imaging 593K-1-3 Advanced Topics in Electrical Engineering-Medical Imaging. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593L - Adv Topics ECE-Mix Signal Test 593L-1-3 Advanced Topics in Electrical Engineering-Mixed-Signal Testing and Design. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593M - Adv Topics ECE-Nanotechnology 593M-1-3 Advanced Topics in Electrical Engineering-Nanotechnology. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593N - Adv Topics ECE-Network Systems 593N-1-3 Advanced Topics in Electrical Engineering-Network Systems. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593O - Adv Topics ECE-Photonics 593O-1-3 Advanced Topics in Electrical Engineering-Photonics. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

ECE593P - Adv Topics ECE-Phys Des Automt 593P-1-3 Advanced Topics in Electrical Engineering-Physical Design Automation. Lectures on advanced topics of special interest to students in various areas
of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

**ECE593Q - Adv Topics ECE-Pwr Elec Conv** 593Q-1-3 Advanced Topics in Electrical Engineering-Power Electronic Converters and Drive Systems. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

**ECE593R - Adv Topics ECE-Power Quality** 593R-1-3 Advanced Topics in Electrical Engineering-Power Quality. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

**ECE593S - Adv Topics ECE-Pwr Sys Con/Pro** 593S-1-3 Advanced Topics in Electrical Engineering-Power System Control and Protection. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

**ECE593T - Adv Topics ECE-Renewbl Energy** 593T-1-3 Advanced Topics in Electrical Engineering-Renewable Energy. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

**ECE593U - Adv Topics ECE-RF/M'Wave Syst** 593U-1-3 Advanced Topics in Electrical Engineering-RF and Microwave Systems. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

**ECE593V - Adv Topics ECE-Signal Process** 593V-1-3 Advanced Topics in Electrical Engineering-Signal Processing. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

**ECE593W - Adv Topics ECE-Software Engr** 593W-1-3 Advanced Topics in Electrical Engineering-Software Engineering. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

**ECE593X - Adv Topics ECE-Wireless System** 593X-1-3 Advanced Topics in Electrical Engineering-Wireless Systems. Lectures on advanced topics of special interest to students in various areas of Electrical & Computer Engineering. This course is designed to offer and test new experimental courses in ECE. Restricted to enrollment in ECE program. Special approval needed from the instructor.

**ECE595 - Communication Skills** 595-3 Communication Skills for Engineering Graduate Students. This course prepares graduate engineering students to communicate technical information to various audiences and for various purposes. Principles and strategies are applied to theses, dissertations, scholarly presentations, and other engineering documents such as lab reports, user manuals, business correspondences, job application materials, and engineering ethics. Research tools and software programs prepare students to deliver oral presentations on current engineering topics. Restricted to graduate standing. Does not count toward the hours required for graduation in the ECE program. Restricted to enrollment in ECE program.

**ECE596 - Principles of BME** 596-3 Principles of Biomedical Engineering. (Same as ECE 460, BME 596) Principles of biomechanics, biomaterials, electrophysiology, modeling, instrumentation, biosignal processing, medical imaging, and biomedical optics. Professional moral and ethical issues in biomedical research and development. Prerequisite: MATH 250 with a grade of C or better or consent of instructor.

**ECE599 - Thesis** 599-1 to 6 Thesis.
ECE600 - Doctoral Dissertation 600-1 to 24 (1 to 16 per semester) Doctoral Dissertation. Dissertation research. Hours and credit to be arranged by director of graduate studies. Graded S/U only. Restricted to Admission to PhD program in Electrical and Computer Engineering.

ECE601 - Continuing Enrollment 601-1 per semester Continuing Enrollment. For those graduate students who have not finished their degree programs and who are in the process of working on their dissertation, thesis, or research paper. The student must have completed a minimum of 24 hours of dissertation research, or the minimum thesis, or research hours before being eligible to register for this course. Concurrent enrollment in any other course is not permitted. Graded S/U or DEF only.

Cybersecurity and Cyber Systems Faculty

School of Computing Faculty

Ahmed, Khaled, Assistant Professor, Ph.D., Tokyo Institute of Technology, 2004; 2019. High-performance computing, distributed and parallel computing, peer-to-peer computing, big data, machine learning, and image processing.


Che, Dunren, Professor, Ph.D., Beijing University of Aeronautics and Astronautics, Beijing China, 1994; 2001. Database, data mining, cloud computing, big data management and analytics.

Gupta, Bidyut, Professor, Ph.D., University of Calcutta, 1986; 1988. Distributed systems, fault-tolerant computing, mobile communication, routing algorithms, peer-to-peer networks.

Hexmoor, Henry, Associate Professor, Ph.D., University of Buffalo, 1996; 2006. Artificial intelligence, Multi-agent systems, cognitive science, mobile robotics, knowledge representation and reasoning.

Hoxha, Bardh, Assistant Professor, Ph.D., Arizona State University, 2017. Formal Methods, Testing and Verification of Cyber-Physical Systems, Motion Planning for Autonomous Vehicles, and Human-Robot Interaction.

Huang, Chun-Hsi, Professor and School Director, Ph.D., State University of New York at Buffalo, 2001; 2019. Extreme-scale computing and data analytics, computational biology, security and applied algorithms.

Huang, Xiaolan, Assistant Professor, Ph.D., Southern Illinois University, 2017; 2019. Bioinformatics, data mining, machine learning, network architecture, data communication and security.

Rekabdar, Banafsheh, Assistant Professor, Ph.D., University of Nevada, 2017. Artificial Intelligence, Machine learning, Deep learning, Data mining, big data analytics, Robotics.

Sinha, Koushik, Assistant Professor, Ph.D., Jadavpur University, 2007; 2015. Mobile and wireless sensor networks, cloud computing and social computing, resource allocation and task scheduling.

School of Electrical, Computer, and Biomedical Engineering Faculty


Anagnostopoulos, Iraklis, Assistant Professor, Ph.D., National Technical University of Athens, 2014; 2015. Many-core architectures, run-time resource management, embedded systems.

Aruma Baduge, Gayan, Assistant Professor, University of Alberta, 2013; 2016. Communications theory, wireless communications, massive MIMO systems, millimeter-wave communications, cooperative relay networks, wireless energy harvesting for IoTs, physical-layer security.

Asrari, Arash, Assistant Professor, Ph.D., University of Central Florida, 2015; 2017. Power systems operation and planning, power systems optimization, smart grid.

Chen, Kang, Assistant Professor, Ph.D., Clemson University, 2014; 2015. Software-defined networking (SDN), network function virtualization (NFV), vehicular networks, mobile opportunistic/ad hoc networks.
Chen, Ying (Ada), Associate Professor, Ph.D., Duke, 2007; 2007. Biomedical imaging, image reconstruction, digital tomosynthesis, image quality analysis, signal and image processing, simulation and computing.

Chilman, Bae, Assistant Professor, Ph.D., Pennsylvania State University, 2009; 2019. Bioelectrical engineering, neuroscience, mechanobiology.

Haniotakis, Themistoklis, Associate Professor, Ph.D., University of Athens, 2008; 2013. Digital VLSI design and test, RF IC design and test, low power VLSI design, and fault-tolerant systems.

Harackiewicz, Frances J., Professor, Ph.D., University of Massachusetts-Amherst, 1990; 1989. Electromagnetics, antenna theory and design, microwaves, microstrip phased arrays and anisotropic materials.

Kagaris, Dimitrios, Professor, Ph.D., Dartmouth College, 1994; 1995. VLSI design automation, digital circuit testing, communication networks.

Komaee, Arash, Assistant Professor, Ph.D., University of Maryland, College Park, 2008; 2015. Control systems, microrobotics, signal processing, estimation theory.

Lu, Chao, Associate Professor, Ph.D., Purdue University, 2012; 2015. VLSI system design, device-circuit co-design, 3D IC.

Qin, Jun, Associate Professor, Ph.D. Duke University, 2008; 2012. Sensors and instrumentation, data acquisition, medical devices, therapeutic ultrasound, haptics.

Sayeh, Mohammad R., Professor, Ph.D., Oklahoma State University, 1985; 1986. Neural networks, optical computing, image processing, stochastic modeling, quantum electronics.

Tragoudas, Spyros, Professor and Director, Ph.D., University of Texas at Dallas, 1991; 1999. Design and test automation for VLSI, embedded systems, computer networks.

Wang, Haibo, Professor, Ph.D., University of Arizona, 2002; 2002. Mixed-signal VLSI design and testing, digital VLSI, VLSI design automation.

Weng, Ning, Professor, Ph.D., University of Massachusetts at Amherst, 2005; 2005. High performance routers, network processors, system-on-a-Chip, computer architectures.

Last updated: 03/23/2021

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