

# SCHOOL OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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Consistent with the mission of the university and college, the mission of the School of Electrical Engineering and Computer Science (EECS) at Oregon State University is to provide a comprehensive, state-of-the-art education that prepares our students to be successful in engineering and computing practice and advanced studies.

The school has a tradition of strong undergraduate programs and one of the largest graduate programs within the university, with internationally recognized research programs in the areas of mixed-signal integration, artificial intelligence and machine learning, computer graphics and vision, energy systems, multimedia and networking, materials and devices, end-user software, human-computer interaction, and signal processing and communications systems.

The School of EECS faculty, advising procedures, undergraduate programs' educational objectives, graduate program application procedures, research areas, and many other aspects may be found at the school's (<http://eecs.oregonstate.edu/>)website. # The Multiple Engineering Cooperative Program (MECOP) offers internships to selected students in the discipline areas of computer science, electrical engineering, and computer engineering.

## Electrical and Computer Engineering

The School of EECS offers programs leading to the BS, MS, MEng, and Ph.D. degrees in Electrical and Computer Engineering (ECE).

Electrical and computer engineers engage in the design, construction and programming, and applications of electronic and integrated circuits, digital computers and embedded systems, power generation and utilization, communication and computer networks, electronic materials and devices, electromagnetic, microwave and optical circuits and systems, control systems, and signal processing and conditioning.

Course work leading to the BS degree consists of courses in many of these topics as well as courses in the supporting disciplines of mathematics, physical sciences, and computer science. Students select further study beyond the required courses for either more depth in a subdiscipline or further breadth across engineering. Students fulfill humanities and social science requirements as specified by the university's baccalaureate core program. The BS program is supported by well-equipped laboratories providing#hands-on#experience with electronic circuits, digital logic, electronic and photonic materials, electric machines, IC design, optoelectronics, RF techniques, instrumentation, and microprocessors.

The program incorporates engineering design principles throughout the undergraduate curriculum. This includes the integration of societal, economic, legal, regulatory, ethical, environmental, and other factors into the technical aspects of engineering design. Design activities begin in the freshman orientation sequence, which incorporates open-ended design problems and continues throughout the curriculum. The design experience culminates with a yearlong senior design project. During the senior design experience, students working in teams complete all phases of a design project under the supervision of a faculty member.

Graduates of this program are prepared to either seek industrial employment or pursue advanced graduate degrees.

The Bachelor of Science and Honors Bachelor of Science degrees in Electrical & Computer Engineering are accredited by the Engineering Accreditation Commission of ABET, <http://www.ABET.org>.

The ECE graduate program provides opportunities for both MS and Ph.D. thesis programs and an#MEng coursework-based program in the following areas: analog/mixed signals, communications and#signal processing, networking and computer systems, energy systems, materials and devices,#and#RF/microwave/mmWave and photonics. Graduate work is supported by the school's well-equipped laboratory facilities. Opportunities exist for graduate students to participate in many research projects sponsored by private industry and government agencies.

The School of Electrical and Computer#Science faculty, advising procedures, undergraduate programs' educational objectives, graduate program application procedures, research areas, and many other aspects may be found at the school's (<http://eecs.oregonstate.edu/>)website

The Multiple Engineering Cooperative Program (MECOP) offers industrial internships to selected students in the discipline areas of computer science, electrical engineering, and computer engineering.

## Computer Science

The School of EECS offers programs leading to BA, BS, MA, MAIS, MEng, MS, and Ph.D. degrees in Computer Science (CS).

Computer science is the heart of cutting-edge computing software. Computer scientists invent software that enables computers to do new things. They design programming languages, compilers, operating systems, games, databases, computer networks, and user interfaces. They solve complex challenging problems in a wide range of fields that can make a positive difference in the world.

Computer science majors learn skills to create realistic graphics, design new problem-solving tools that anyone can use, and create new solutions for business, medicine, and entertainment. Their programming skills enable computers to 'learn' as they process data as well as assist in social communication and technologies to improve the lives of disadvantaged persons.

Computer science offers a foundation that allows graduates to make software work well, make it fast, make it work correctly, find where innovation is needed, and understand the people who will be using it, so as to make it genuinely useful and compelling to people. Much of computer science course work is carried out in teams, and students gain experience in teamwork, professionalism in writing, working with clients, and making presentations of their teams' efforts.

Course work leading to the BS degree consists of required courses in many of these topics, as well as courses in supporting disciplines such as mathematics. The BS program is supported by well-equipped computer laboratories. Students select further study beyond the required core courses, opting for more depth in computer science, more breadth in business and entrepreneurship, or grounding in an application area for their computing skills. The BS program culminates with a yearlong senior capstone project, where students working in teams complete all phases of a software project under the supervision of a faculty member.

Graduates of this program are prepared either to pursue advanced graduate degrees or seek employment in business, industry or government.

The Bachelor of Science (BS) and Honors Bachelor of Science (HBS) degrees for the Computer Systems Option (CSO) of the Computer Science program are accredited by the Computing Accreditation Commission of ABET, <http://www.ABET.org>.

The CS graduate program provides opportunities for MS and Ph.D. thesis, MS non-thesis, and MEng coursework-based degrees in the following areas: artificial intelligence, machine learning & data sciences, computer graphics, visualization & vision, cybersecurity & cryptography, networking & computer systems, human-computer interaction, programming languages, software engineering, and theoretical computer science. Graduate work is supported by the school's well-equipped laboratory facilities. Opportunities exist for graduate students to participate in many research projects sponsored by private industry and government agencies.

The School of Electrical and Computer Science faculty, advising procedures, undergraduate programs' educational objectives, graduate program application procedures, research areas, and many other aspects may be found at the school's (<http://eecs.oregonstate.edu/>) website.

The Multiple Engineering Cooperative Program (MECOP) offers internships to selected students in the discipline areas of computer science, electrical engineering, and computer engineering.

## Undergraduate Programs

### Majors

- Computer Science (<http://catalog.oregonstate.edu/college-departments/engineering/school-electrical-engineering-computer-science/computer-science-ba-bs-hba-hbs/>)  
**Options:**
  - *Applied Computer Science*
  - *Computer Science Double Degree*
  - *Computer Systems*
- Electrical and Computer Engineering (<http://catalog.oregonstate.edu/college-departments/engineering/school-electrical-engineering-computer-science/electrical-computer-engineering-bs-hbs/>)

### Minor

- Computer Science (<http://catalog.oregonstate.edu/college-departments/engineering/school-electrical-engineering-computer-science/computer-science-minor/>)

### Certificate

- CyberSecurity (<http://catalog.oregonstate.edu/college-departments/engineering/school-electrical-engineering-computer-science/cybersecurity-certificate/>)

## Graduate Programs

### Majors

- Computer Science (<http://catalog.oregonstate.edu/college-departments/engineering/school-electrical-engineering-computer-science/computer-science-meng-ms-phd/>)

- Electrical and Computer Engineering (<http://catalog.oregonstate.edu/college-departments/engineering/school-electrical-engineering-computer-science/electrical-computer-engineering-meng-ms-phd/>)

### Minors

- Computer Science (<http://catalog.oregonstate.edu/college-departments/engineering/school-electrical-engineering-computer-science/computer-science-graduate-minor/>)
- Electrical and Computer Engineering (<http://catalog.oregonstate.edu/college-departments/engineering/school-electrical-engineering-computer-science/electrical-computer-engineering-graduate-minor/>)

**Tom Weller, School Head**

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Oregon State University  
Corvallis, OR 97331-5501  
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## Faculty

**Distinguished Professor** Dietterich

**Professors** Adams, Allstot, Bailey, Bose, Brekken, Burnett, Conley, Cull (Emeritus), Dhagat, Erwig, A. Fern, Hamdaoui, Lee, Liu, Mathews, Mayaram, Moon, Nguyen, Pancake (Emeritus), Tadepalli, Temes, Wager (Emeritus), Weller, Weisshaar, E. Zhang

**Associate Professors** Borradaile, Budd (Emeritus), Chiang, Cotilla-Sanchez, de Amicis, Dig, X. Fern, Jander, Jensen, Magaña, Minoura (Emeritus), Natarajan, Plant (Emeritus), Raich, Sarma, Scaffidi, Todorovic, Wang, Wong

**Assistant Professors** T. Anand, Bobba, Cao, L. Chen, Cheng, Fu, Hendrix, L. Huang, Hutchinson, Jang, Johnston, Kim, Knight, Labram, F. Li, Natarajan, Nayyeri, Parham-Mocello, Ramsey, Rosulek, Termehchy, Walkingshaw

**Senior Instructor** Traylor, McGrath

**Instructors** Alcon, Bakos, Brewster, Cate, Ehsan, Goins, Redfield, Rooker, Schutfort, Shuman, Sweet, Van Londen, Winters, Wolford, L. Zhang

**Faculty Research Assistant 1** Heer, Irvine

**Associate Professor Senior Research** Y. Zhang

### Computer Science (CS)

#### CS 101, COMPUTERS: APPLICATIONS AND IMPLICATIONS, 4 Credits

The varieties of computer hardware and software. The effects, positive and negative, of computers on human lives. Ethical implications of information technology. Hands-on experience with a variety of computer applications. Lec/lab.

*Available via Ecampus*

#### CS 160, COMPUTER SCIENCE ORIENTATION, 3 Credits

Introduction to the computer science field and profession. Team problem solving. Introduction to writing computer programs. Approaches to teaching course topics vary across sections. Lec/lab.

**Equivalent to:** CS 160H

*Available via Ecampus*

## CS 160H, COMPUTER SCIENCE ORIENTATION, 3 Credits

Introduction to the computer science field and profession. Team problem solving. Introduction to writing computer programs. Approaches to teaching course topics vary across sections. Lec/lab.

**Attributes:** HNRS – Honors Course Designator

**Equivalent to:** CS 160

## CS 161, INTRODUCTION TO COMPUTER SCIENCE I, 4 Credits

Overview of fundamental concepts of computer science. Introduction to problem solving, software engineering, and object-oriented programming. Includes algorithm design and program development. Lec/lab/rec.

**Prerequisite:** MTH 112 (may be taken concurrently) with C or better or Math Placement Test with a score of 33 or Math Placement - ALEKS with a score of 061

**Equivalent to:** EECS 161

*Available via Ecampus*

## CS 162, INTRODUCTION TO COMPUTER SCIENCE II, 4 Credits

Basic data structures. Computer programming techniques and application of software engineering principles. Introduction to analysis of programs. Lec/lab/rec.

**Prerequisite:** CS 161 with C or better or EECS 161 with C or better

**Equivalent to:** EECS 162

*Available via Ecampus*

## CS 165, ACCELERATED INTRODUCTION TO COMPUTER SCIENCE, 8 Credits

Overview of the fundamental concepts of computer science. Introduction to problem solving, algorithm development, data types, and basic data structures. Introduction to analysis of algorithms and principles of software engineering. System development and computer programming using procedural/object-oriented paradigms. Offered via Ecampus only.

**Prerequisite:** MTH 112 with C or better or Math Placement - ALEKS with a score of 075

*Available via Ecampus*

## CS 175, \*COMMUNICATIONS SECURITY AND SOCIAL MOVEMENTS, 3 Credits

Equipping students with the theory and practice of communications security, this course explores how social movements can remain effective in the context of mass surveillance and state repression. Lec/rec. (Bacc Core Course)

**Attributes:** CPDP – Core, Perspective, Difference/Power/Discrimination

## CS 195, WEBSITE DESIGN, 4 Credits

How to design and publish a static website using an existing publishing platform: Techniques and tools for designing and publishing on the World Wide Web; hypertext and HTML; site and page design; media integration; issues raised by Internet publishing.

**Equivalent to:** CS 295

## CS 199, SPECIAL TOPICS/COMPUTER SCIENCE, 1-16 Credits

*This course is repeatable for 16 credits.*

*Available via Ecampus*

## CS 201, COMPUTER PROGRAMMING FOR NON-CS MAJORS, 3 Credits

Covers a variety of fundamental topics in computer programming relevant to anyone who wants to write or work with computer code in their work or studies. Teaches basic computational thinking and programming skills which will allow students to solve a variety of real-world problems. In addition, students will learn more advanced topics such as how some basic algorithms work and can be written in computer code.

**Prerequisite:** MTH 111 with C- or better

*Available via Ecampus*

## CS 225, DISCRETE STRUCTURES IN COMPUTER SCIENCE, 4 Credits

An introduction to the discrete mathematics of computer science, including logic, set and set operations, methods of proof, recursive definitions, combinatorics, and graph theory. (Note: Students may take either MTH 231 or CS 225, but cannot receive credit for both.)

**Prerequisite:** MTH 111 with C or better or Math Placement Test with a score of 24 or Math Placement - ALEKS with a score of 061 or MTH 112 (may be taken concurrently) with C or better

*Available via Ecampus*

## CS 261, DATA STRUCTURES, 4 Credits

Abstract data types, dynamic arrays, linked lists, trees and graphs, binary search trees, hash tables, storage management, complexity analysis of data structures. Lec/rec.

**Prerequisite:** (CS 162 with C or better or CS 165 with C or better) and (CS 225 [C] or MTH 231 [C])

**Equivalent to:** EECS 261

*Available via Ecampus*

## CS 262, PROGRAMMING PROJECTS IN C++, 4 Credits

Learning a second computer programming language. Elements of C ++. Object-oriented programming. Experience team work on a large programming project.

**Prerequisite:** CS 261 with C or better

## CS 271, COMPUTER ARCHITECTURE AND ASSEMBLY LANGUAGE, 4 Credits

Introduction to functional organization and operation of digital computers. Coverage of assembly language; addressing, stacks, argument passing, arithmetic operations, decisions, macros, modularization, linkers and debuggers.

**Prerequisite:** CS 151 with C or better or CS 161 with C or better or CS 165 with C or better

*Available via Ecampus*

## CS 290, WEB DEVELOPMENT, 4 Credits

How to design and implement a multi-tier application using web technologies: Creation of extensive custom client- and server-side code, consistent with achieving a high-quality software architecture.

**Prerequisite:** CS 162 with C or better or CS 165 with C or better

**Equivalent to:** CS 494

*Available via Ecampus*

## CS 295, WEBSITE MANAGEMENT, 4 Credits

How to create and promote a dynamic website using existing frameworks/libraries: Designing, developing, publishing, maintaining, and marketing dynamic websites; web security and privacy issues; emerging web technologies; running a website marketing campaign.

**Prerequisite:** CS 195 with C or better

**Recommended:** Basic HTML and CSS

## CS 299, SPECIAL TOPICS, 0-4 Credits

*This course is repeatable for 99 credits.*

## CS 312, SYSTEM ADMINISTRATION, 4 Credits

Introduction to system administration. Network administration and routing. Security issues. Computer, server, and network hardware. Lec/lab.

**Prerequisite:** (CS 311 with C or better or CS 344 with C or better) and CS 372 [C]

## CS 321, INTRODUCTION TO THEORY OF COMPUTATION, 3 Credits

Survey of models of computation including finite automata, formal grammars, and Turing machines.

**Prerequisite:** CS 261 with C or better and (CS 225 [C] or MTH 231 [C])

**Equivalent to:** CS 321H

*Available via Ecampus*

## CS 321H, INTRODUCTION TO THEORY OF COMPUTATION, 3 Credits

Survey of models of computation including finite automata, formal grammars, and Turing machines.

**Attributes:** HNRS – Honors Course Designator

**Prerequisite:** CS 261 with C or better and (CS 225 [C] or MTH 231 [C])

**Equivalent to:** CS 321

## CS 325, ANALYSIS OF ALGORITHMS, 4 Credits

Recurrence relations, combinatorics, recursive algorithms, proofs of correctness.

**Prerequisite:** CS 261 with C or better and (CS 225 [C] or MTH 231 [C])

**Equivalent to:** CS 325H

*Available via Ecampus*

## CS 325H, ANALYSIS OF ALGORITHMS, 4 Credits

Recurrence relations, combinatorics, recursive algorithms, proofs of correctness.

**Attributes:** HNRS – Honors Course Designator

**Prerequisite:** CS 261 with C or better and (CS 225 [C] or MTH 231 [C])

**Equivalent to:** CS 325

## CS 331, INTRODUCTION TO ARTIFICIAL INTELLIGENCE, 4 Credits

Fundamental concepts in artificial intelligence using the unifying theme of an intelligent agent. Topics include agent architectures, search, games, logic and reasoning, and Bayesian networks.

**Prerequisite:** CS 325 with C or better or CS 325H with C or better

## CS 340, INTRODUCTION TO DATABASES, 4 Credits

Design and implementation of relational databases, including data modeling with ER or UML, diagrams, relational schema, SQL queries, relational algebra, user interfaces, and administration.

**Prerequisite:** CS 290 with C or better

**Equivalent to:** CS 275

*Available via Ecampus*

## CS 344, OPERATING SYSTEMS I, 4 Credits

Introduction to operating systems using UNIX as the case study.

System calls and utilities, fundamentals of processes and interprocess communication.

**Prerequisite:** CS 261 with C or better and (CS 271 [C] or ECE 271 [C])

**Equivalent to:** CS 311

**Recommended:** Experience programming in the C language

*Available via Ecampus*

## CS 352, INTRODUCTION TO USABILITY ENGINEERING, 4 Credits

Basic principles of usability engineering methods for the design and evaluation of software systems. Includes the study of human-machine interactions, user interface characteristics and design strategies, software evaluation methods, and related guidelines and standards.

**Prerequisite:** CS 151 with C or better or CS 161 with C or better or CS 165

with C or better or CS 295 with C or better or ECE 151 with C or better

**Equivalent to:** CS 252

*Available via Ecampus*

## CS 361, SOFTWARE ENGINEERING I, 4 Credits

Introduction to the 'front end' of the software engineering lifecycle; requirements analysis and specification; design techniques; project management.

**Prerequisite:** CS 261 with C or better

*Available via Ecampus*

## CS 362, SOFTWARE ENGINEERING II, 4 Credits

Introduction to the 'back end' of the software engineering lifecycle implementation; verification and validation; debugging; maintenance.

**Prerequisite:** CS 261 with C or better

**Recommended:** Experience with object-oriented programming and data structures (eg. CS 161, CS 162, CS 361)

*Available via Ecampus*

## CS 370, INTRODUCTION TO SECURITY, 4 Credits

Introductory course on computer security with the objective to introduce concepts and principles of computer systems security. Notions of security, basic cryptographic primitives and their application, basics of authentication and access control, basics of key-management, basics of malware and software security.

**Prerequisite:** CS 344 (may be taken concurrently) with C or better

*Available via Ecampus*



## CS 372, INTRODUCTION TO COMPUTER NETWORKS, 4 Credits

Computer network principles, fundamental networking concepts, packet-switching and circuit switching, TCP/IP protocol layers, reliable data transfer, congestion control, flow control, packet forwarding and routing, MAC addressing, multiple access techniques. CROSSLISTED as CS 372/ECE 372.

**Prerequisite:** CS 261 with C or better and (ECE 271 [C] or CS 271 [C])

**Equivalent to:** ECE 372

**Recommended:** C programming and Unix familiarity.

Available via Ecampus

## CS 373, DEFENSE AGAINST THE DARK ARTS, 4 Credits

Introduction to the current state of the art in anti-malware, computer forensics, and networking, messaging, and web security. Broad introduction to the field of computer security.

**Prerequisite:** CS 344 with C or better and CS 340 [C] and CS 372 [C]

Available via Ecampus

## CS 381, PROGRAMMING LANGUAGE FUNDAMENTALS, 4 Credits

An introduction to the concepts found in a variety of programming languages. Programming languages as tools for problem solving. A brief introduction to languages from a number of different paradigms.

**Prerequisite:** CS 261 with C or better and (CS 225 [C] or MTH 231 [C])

Available via Ecampus

## CS 391, \*SOCIAL AND ETHICAL ISSUES IN COMPUTER SCIENCE, 3 Credits

In-depth exploration of the social, psychological, political, and ethical issues surrounding the computer industry and the evolving information society. (Bacc Core Course)

**Attributes:** CSST – Core, Synthesis, Science/Technology/Society

**Equivalent to:** CS 391H, CS 391H

**Recommended:** CS 101 or computer literacy.

Available via Ecampus

## CS 391H, \*SOCIAL AND ETHICAL ISSUES IN COMPUTER SCIENCE, 3 Credits

In-depth exploration of the social, psychological, political, and ethical issues surrounding the computer industry and the evolving information society. (Bacc Core Course)

**Attributes:** CSST – Core, Synthesis, Science/Technology/Society; HNRS – Honors Course Designator

**Equivalent to:** CS 391

**Recommended:** CS 101 or computer literacy

## CS 395, WEBSITE MULTIMEDIA, 4 Credits

How to create and deploy interactive digital multimedia through static websites: Technological, aesthetic, and pedagogical issues of communication using interactive multimedia and hypermedia; techniques for authoring interactive multimedia projects using a variety of digital media roots.

**Prerequisite:** CS 195 with C or better or (ART 120 with C or better and (CS 162 [C] or CS 165 [C]))

## CS 399, SPECIAL TOPICS, 0-4 Credits

This course is repeatable for 99 credits.

## CS 401, RESEARCH, 1-16 Credits

This course is repeatable for 16 credits.

## CS 403, THESIS, 1-16 Credits

This course is repeatable for 16 credits.

## CS 405, READING AND CONFERENCE, 1-16 Credits

This course is repeatable for 16 credits.

## CS 406, PROJECTS, 1-16 Credits

This course is repeatable for 16 credits.

Available via Ecampus

## CS 407, SEMINAR, 1-16 Credits

Graded P/N.

**Equivalent to:** CS 407H

This course is repeatable for 16 credits.

## CS 407H, SEMINAR, 1-16 Credits

Graded P/N.

**Attributes:** HNRS – Honors Course Designator

**Equivalent to:** CS 407

This course is repeatable for 16 credits.

## CS 410, OCCUPATIONAL INTERNSHIP, 1-16 Credits

Graded P/N.

This course is repeatable for 16 credits.

## CS 419, SELECTED TOPICS IN COMPUTER SCIENCE, 0-5 Credits

Topics of special and current interest not covered in other courses.

**Equivalent to:** CS 419H

This course is repeatable for 99 credits.

Available via Ecampus

## CS 419H, SELECTED TOPICS IN COMPUTER SCIENCE, 1-5 Credits

Topics of special and current interest not covered in other courses.

**Attributes:** HNRS – Honors Course Designator

**Equivalent to:** CS 419

This course is repeatable for 99 credits.

## CS 420, GRAPH THEORY WITH APPLICATIONS TO COMPUTER SCIENCE, 3 Credits

Directed and undirected graphs; paths, circuits, trees, coloring, planar graphs, partitioning; computer representation of graphs and graph algorithms; applications in software complexity metrics, program testing, and compiling.

**Prerequisite:** (CS 325 with C or better or CS 325H with C or better)

## CS 427, CRYPTOGRAPHY, 4 Credits

Introduction to the theory and practice of modern cryptography. Fundamental primitives including pseudorandom generators, block ciphers, hash functions. Symmetric-key cryptography for privacy and authenticity. Public-key cryptography based on number-theoretic problems.

**Prerequisite:** CS 261 with C or better or MTH 355 with C or better  
*Available via Ecampus*

## CS 434, MACHINE LEARNING AND DATA MINING, 4 Credits

Introduction to machine learning and data mining algorithms (supervised learning, unsupervised learning, and reinforcement learning) tools that are widely employed in industrial and research settings.

**Prerequisite:** CS 325 with C or better or CS 325H with C or better

## CS 440, DATABASE MANAGEMENT SYSTEMS, 4 Credits

Relational database design, normalization, file structures, disk storage, query processing and optimization, team development of database applications.

**Prerequisite:** CS 261 with C or better and CS 340 [C]

## CS 444, OPERATING SYSTEMS II, 4 Credits

Explores principles of computer operating systems: concurrent processes, memory management, job scheduling, multiprocessing, file systems, performance evaluation, and networking.

**Prerequisite:** CS 344 with C or better and (CS 271 [C] or ECE 375 [C])  
**Equivalent to:** CS 411

## CS 446, NETWORKS IN COMPUTATIONAL BIOLOGY, 3 Credits

An introduction to biological networks and computational methods for their analysis, inference, and functional modeling. Various network centralities, topological measures, clustering algorithms, and probabilistic annotation models are introduced in the context of protein interaction, gene regulatory, and metabolic networks. Surveys bioinformatics methods for data-driven inference of network structure.

**Prerequisite:** CS 261 with C or better or BOT 476 with C or better  
**Recommended:** Completion or concurrent enrollment in CS 325

## CS 447, WIRELESS EMBEDDED SYSTEMS, 4 Credits

A hands-on introduction to programming wireless embedded systems (aka the 'Internet of Things'). Topics include sensors, actuators, state machines, scheduling, wireless communications, time synchronization, localization, fault tolerance, and security related to cyber-physical systems.

**Prerequisite:** CS 344 with C or better

## CS 450, INTRODUCTION TO COMPUTER GRAPHICS, 4 Credits

Theoretical and practical treatment of 3D computer graphics using OpenGL: geometric modeling, transformations, viewing, lighting, texture mapping, shading, rendering, and animation.

**Prerequisite:** CS 261 with C or better

## CS 453, SCIENTIFIC VISUALIZATION, 4 Credits

Applies 3D computer graphics methods to visually understand scientific and engineering data. Methods include hyperbolic projections; mapping scalar values to color spaces; data visualization using range sliders; scalar visualization (point clouds, cutting planes, contour plots, isosurfaces); vector visualization (arrow clouds, particle advection, streamlines); terrain visualization; Delauney triangulation; and volume visualization.

**Prerequisite:** CS 261 with C or better

**Recommended:** Prior experience with Unix or Windows, programming experience.

## CS 457, COMPUTER GRAPHICS SHADERS, 4 Credits

Theoretical and practical treatment of computer graphics shaders, including both RenderMan and GPU shaders. Programming in both RenderMan and OpenGL shading languages.

**Recommended:** Previous graphics pipeline programming experience.

## CS 458, INTRODUCTION TO INFORMATION VISUALIZATION, 4 Credits

Tools and techniques for designing, developing, and deploying interactive visualizations of abstract data sources. Discusses techniques based on principles from design, cognitive science, and perceptual psychology.

Topics include 1D, 2D, 3D, multivariate representations, time-series, graphs and trees, text and documents, and interaction techniques.

**Prerequisite:** CS 361 with C or better

## CS 461, ^SENIOR SOFTWARE ENGINEERING PROJECT I, 3 Credits

Utilize software engineering methodology in a team environment to develop a real-world application. Teams will be responsible for all phases of software development, including project planning, requirements analysis, design, coding, testing, configuration management, quality assurance, documentation, and delivery. (Writing Intensive Course)

**Attributes:** CWIC – Core, Skills, WIC

**Prerequisite:** CS 361 with C or better and CS 325 [C] and CS 362 [C]  
*Available via Ecampus*

## CS 462, ^SENIOR SOFTWARE ENGINEERING PROJECT II, 3 Credits

Utilize software engineering methodology in a team environment to develop a real-world application. Teams will be responsible for all phases of software development, including project planning, requirements analysis, design, coding, testing, configuration management, quality assurance, documentation, and delivery. Three-term sequence required. (Writing Intensive Courses)

**Attributes:** CWIC – Core, Skills, WIC

**Prerequisite:** CS 362 with C or better and CS 461 [C]

## CS 463, SENIOR SOFTWARE ENGINEERING PROJECT, 2 Credits

Utilize software engineering methodology in a team environment to develop a real-world application. Teams will be responsible for all phases of software development, including project planning, requirements analysis, design, coding, testing, configuration management, quality assurance, documentation, and delivery. Three-term sequence required.

**Prerequisite:** CS 462 with C or better

## CS 464, OPEN SOURCE SOFTWARE, 4 Credits

Provides a theoretical foundation of the history, key concepts, technologies, and practices associated with modern Free and Open Source Software (FOSS) projects, and gives students an opportunity to explore and make contributions to FOSS projects with some mentoring and guidance.

**Prerequisite:** CS 261 with C or better and CS 361 [C]

*Available via Ecampus*

## CS 466, WEB-BASED START-UP PROJECT, 4 Credits

Real-world, hands-on learning in a high-tech web/mobile-based company environment. Research in the development of product ideas, hypotheses, and business models to create customer experiments. Prototyping and statistical analysis to develop, optimize, and evaluate solutions. Rapid iteration/refactoring based on customer input, web analytics, and user engagement metrics. Offered at OSU-Cascades only.

**Corequisites:** CS 461

## CS 467, ONLINE CAPSTONE PROJECT, 4 Credits

Real-world team-based experience with the software engineering design and delivery cycle, including requirements analysis and specification, design techniques, and requirements and final project written documentation. For students in the online CS double-degree program only.

**Prerequisite:** CS 344 with C or better and CS 361 [C] and CS 362 [C]

*Available via Ecampus*

## CS 468, INCLUSIVE DESIGN (HCI), 4 Credits

Inclusive design is designing software that works for a wide variety of differently abled customers. Teaches the skills needed to design inclusively without having to have a separate design for each differently abled customer.

**Prerequisite:** CS 352 with C or better

**Recommended:** CS 565 with a minimum grade of C

## CS 472, COMPUTER ARCHITECTURE, 4 Credits

Computer architecture using processors, memories, and I/O devices as building blocks. Issues involved in the design of instruction set architecture, processor, pipelining and memory organization. Design philosophies and trade-offs involved in Reduced Instruction Set Computer (RISC) architectures. Lec/lab. CROSMLISTED as CS 472/ECE 472 and CS 572/ECE 572.

**Prerequisite:** ECE 375 with C or better

**Equivalent to:** CS 470, ECE 472

## CS 475, INTRODUCTION TO PARALLEL PROGRAMMING, 4 Credits

Theoretical and practical survey of parallel programming, including a discussion of parallel architectures, parallel programming paradigms, and parallel algorithms. Programming one or more parallel computers in a higher-level parallel language.

**Prerequisite:** CS 261 with C or better

*Available via Ecampus*

## CS 476, ADVANCED COMPUTER NETWORKING, 4 Credits

Advanced networking concepts: source/channel coding, queuing theory, router design, network architectures (Intserv, DiffServ, MPLS), multimedia protocols (TFRC, RTP), overlay networks, and wireless standards (Bluetooth 802.11b, 3/4G). CROSMLISTED as CS 476/ECE 476 and CS 576/ECE 576.

**Prerequisite:** (CS 372 with C or better or ECE 372 with C or better) and (ECE 353 [C] or ST 314 [C] or ST 314H [C])

**Equivalent to:** ECE 476, EECS 476

## CS 477, INTRODUCTION TO DIGITAL FORENSICS, 4 Credits

Introduces concepts related to digital forensics, its role and importance, and tools and techniques for collecting and curating digital evidence. The course will also discuss the role of evidence in the justice system and some legal aspects as they pertain to digital forensics. It will introduce tools and techniques for computer and network forensics.

**Prerequisite:** CS 344 with C or better and CS 370 [C]

*Available via Ecampus*

## CS 478, NETWORK SECURITY, 4 Credits

Basic concepts and techniques in network security, risks and vulnerabilities, applied cryptography and various network security protocols. Coverage of high-level concepts such as authentication, confidentiality, integrity, and availability applied to networking systems. Fundamental techniques including authentication protocols, group key establishment and management, trusted intermediaries, public key infrastructures, SSL/TLS, IPsec, firewalls and intrusion detection CROSMLISTED as CS 478/ECE 478.

**Prerequisite:** CS 372 with C or better or ECE 372 with C or better

**Equivalent to:** ECE 478

**Recommended:** CS 370

*Available via Ecampus*

## CS 480, TRANSLATORS, 4 Credits

Explores content on the subject of compilers; attribute grammars, syntax-directed translation, lex, yacc, LR(1) parsers, symbol tables, semantic analysis, and peep-hole optimization.

**Prerequisite:** CS 344 with C or better and CS 381 [C] and (CS 321 [C] or CS 321H [C])

## CS 491, COMPUTER SCIENCE SKILLS FOR SIMULATION AND GAME PROGRAMMING, 4 Credits

Game and simulation development is very much a data and math-intensive activity. A certain number of actions must be produced, and producing them by hand is hard. This is a middleware CS course that fills in many of the missing pieces for those wanting to enter the simulation and game development worlds in a software tool-building capacity.

**Prerequisite:** CS 261 with C or better and (CS 225 [C] or MTH 231 [C]) and MTH 252 [C]

## CS 492, MOBILE SOFTWARE DEVELOPMENT, 4 Credits

Introduction to concepts and techniques for developing mobile applications. Students will become familiar with modern mobile structure, implementation, development tools, and workflow.

**Prerequisite:** CS 344 with C or better

Available via Ecampus

## CS 493, CLOUD APPLICATION DEVELOPMENT, 4 Credits

Covers developing RESTful cloud services, an approach based on representational state transfer technology, an architectural style and approach to communications used in modern cloud services development.

**Prerequisite:** CS 290 with C or better and CS 340 [C] and CS 372 [C]

Available via Ecampus

## CS 495, INTERACTIVE MULTIMEDIA PROJECTS, 4 Credits

Students apply principles and procedures of digital art, design, communication, and software authoring while working on large integrated media projects.

**Recommended:** CS 395

## CS 496, MOBILE AND CLOUD SOFTWARE DEVELOPMENT, 4 Credits

Introduction to the concepts and techniques for developing mobile and cloud applications.

**Prerequisite:** CS 344 with C or better or CS 311 with C or better

**Recommended:** Working knowledge of at least one operating system

## CS 499, SPECIAL TOPICS, 0-16 Credits

*This course is repeatable for 16 credits.*

## CS 501, RESEARCH, 1-16 Credits

Graded P/N.

*This course is repeatable for 99 credits.*

## CS 503, COMPUTER SCIENCE MS THESIS, 1-16 Credits

*This course is repeatable for 999 credits.*

## CS 505, READING AND CONFERENCE, 1-16 Credits

*This course is repeatable for 20 credits.*

## CS 506, PROJECTS, 1-16 Credits

Graded P/N.

*This course is repeatable for 99 credits.*

## CS 507, SEMINAR, 1-16 Credits

Graded P/N.

*This course is repeatable for 16 credits.*

## CS 510, OCCUPATIONAL INTERNSHIP, 1-4 Credits

*This course is repeatable for 99 credits.*

Available via Ecampus

## CS 511, PROGRAMMING AND DATA STRUCTURES, 4 Credits

Computer programming, problem solving, data structures, object-oriented programming, recursion, sorting, dynamic programming, asymptotic time complexity

**Recommended:** College algebra, plus the ability to navigate an operating system, manipulate files, and use a command line.

Available via Ecampus

## CS 512, DATA SCIENCE TOOLS AND PROGRAMMING, 4 Credits

Accessing and distributing data in the cloud; relational and non-relational databases; map reduction; cloud data processing; load balancing; types of data-stores used in the cloud.

**Recommended:** CS 511 or an equivalent course or programming experience in a high-level language like Python, Java or C++.

Available via Ecampus

## CS 515, ALGORITHMS AND DATA STRUCTURES, 4 Credits

Greedy algorithms, divide and conquer, dynamic programming, network flow, data structures.

**Recommended:** Undergraduate course in algorithms

## CS 516, THEORY OF COMPUTATION AND FORMAL LANGUAGES, 4 Credits

Models of computation. Universal machines. Unsolvable problems. Nondeterministic computation. Chomsky hierarchy: regular, context-free, context-sensitive and unrestricted grammars; characterization, closure properties, algorithms, and limitations.

## CS 517, THEORY OF COMPUTATION, 4 Credits

Turing machines, decidability, NP-completeness, complexity classes, randomized computation, relativization, circuit complexity, interactive proof systems, lower bounds, cryptography.

## CS 519, SELECTED TOPICS IN COMPUTER SCIENCE, 0-5 Credits

Topics of special and current interest not covered in other courses. May not be offered every year.

*This course is repeatable for 99 credits.*

Available via Ecampus



## CS 520, GRAPH THEORY WITH APPLICATIONS TO COMPUTER SCIENCE, 3 Credits

Directed and undirected graphs; paths, circuits, trees, coloring, planar graphs, partitioning; computer representation of graphs and graph algorithms; applications in software complexity metrics, program testing, and compiling.

**Recommended:** CS 325 and MTH 232

## CS 523, ADVANCED ALGORITHMS, 4 Credits

Approximation algorithms, randomized and probabilistic algorithms, online algorithms.

**Recommended:** CS 515

## CS 527, ERROR-CORRECTING CODES, 4 Credits

Hamming codes, linear codes, cyclic codes, BCH and Reed-Solomon codes. Introduction to Galois fields. Encoding and decoding algorithms. Burst error correcting codes, asymmetric and unidirectional codes. Applications of codes for computer systems.

**Recommended:** Discrete math and probability

## CS 529, SELECTED TOPICS IN THEORETICAL COMPUTER SCIENCE, 1-5 Credits

Topics of interest in algorithms and theory of computation. Topics include approximation algorithms, planar graph algorithms, distributed algorithms, combinatorial optimization, computational geometry.

*This course is repeatable for 99 credits.*

**Recommended:** CS 515

## CS 531, ARTIFICIAL INTELLIGENCE, 4 Credits

Intelligent agents. Problem-solving as heuristic search. Adversarial search. Constraint satisfaction methods; Arc-consistency. Knowledge representation and reasoning. Propositional logic. Reasoning with propositional logic: algorithms for satisfiability. First-order logic. Proof theory, model theory, resolution refutation, forward and backward chaining, representing events and actions. Lec/lab.

## CS 533, INTELLIGENT AGENTS AND DECISION MAKING, 4 Credits

Representations of agents, execution architectures. Planning: non-linear planning, graphplan, SATplan. Scheduling and resource management. Probabilistic agents. Dynamic belief networks. Dynamic programming (value iteration and policy iteration). Reinforcement learning: Prioritized sweeping, Q learning, value function approximation and SARSA ( $\lambda$ ), policy gradient methods.

**Recommended:** CS 531

## CS 534, MACHINE LEARNING, 4 Credits

Continuous representations. Bias-variance tradeoff. Computational learning theory. Gaussian probabilistic models. Linear discriminants. Support vector machines. Neural networks. Ensemble methods. Feature extraction and dimensionality reduction methods. Factor analysis. Principle component analysis. Independent component analysis. Cost-sensitive learning.

## CS 535, DEEP LEARNING, 4 Credits

An introduction to the concepts and algorithms in deep learning; basic feedforward neural networks, convolutional neural networks, recurrent neural networks including long short-term memory models, deep belief nets, autoencoders and deep networks applications in computer vision, natural language processing and reinforcement learning.

**Prerequisite:** CS 534 with C or better or ROB 537 with C or better

## CS 536, PROBABILISTIC GRAPHICAL MODELS, 4 Credits

Representation of probabilistic graphical models, both directed (Bayesian networks) and undirected (Markov networks). Exact and approximate inference techniques. Parameter and structure learning from data.

**Recommended:** Strong programming skills

## CS 537, COMPUTER VISION I, 3 Credits

An introduction to low-level computer vision and visual geometry. Topics of interest include the following: detection of interest points and edges, matching points and edges, color models, projective geometry, camera calibration, epipolar geometry, homography, image stitching, and multitarget tracking.

**Recommended:** Undergraduate-level statistics, probability, calculus, linear algebra, good programming skills, machine learning or AI

## CS 539, SELECTED TOPICS IN ARTIFICIAL INTELLIGENCE, 0-5 Credits

Advanced topics in artificial intelligence. Typical topics include machine learning for sequential and spatial data, knowledge representation and inference, probabilistic modeling of complex systems, data mining and information extraction.

*This course is repeatable for 99 credits.*

## CS 540, DATABASE MANAGEMENT SYSTEMS, 4 Credits

Purpose of database systems, levels of data representation. Entity-relationship model. Relational systems: data definition, data manipulation, query language (SQL), relational calculus and algebra, data dependencies and normal forms. DBTG network model. Query optimization, recovery, concurrency control.

**Recommended:** CS 261

## CS 544, OPERATING SYSTEMS II, 4 Credits

Principles of computer operating systems: concurrent processes, memory management, job scheduling, multiprocessing, file systems, performance evaluation, and networking. Lec/rec.

**Equivalent to:** CS 511

**Recommended:** (CS 311 or CS 344) and (CS 271 or ECE 375)

## CS 546, NETWORKS IN COMPUTATIONAL BIOLOGY, 3 Credits

An introduction to biological networks and computational methods for their analysis, inference, and functional modeling. Various network centralities, topological measures, clustering algorithms, and probabilistic annotation models are introduced in the context of protein interaction, gene regulatory, and metabolic networks. Surveys bioinformatics methods for data-driven inference of network structure.

**Recommended:** Completion or concurrent enrollment in CS 325

## CS 549, SELECTED TOPICS ON DATA SCIENCE & SYSTEMS, 0-5 Credits

Current topics in data science and systems, e.g. querying, inference, and learning over large datasets; reasoning and learning on graph, heterogeneous, and multi-modal data; data curation; knowledge representation; systems for large data exploration and analytics; distributed data systems; human-centered data science; fairness and responsibility in data science.

*This course is repeatable for 99 credits.*

**Recommended:** CS 540

## CS 550, INTRODUCTION TO COMPUTER GRAPHICS, 4 Credits

Theoretical and practical treatment of 3D computer graphics using OpenGL: geometric modeling, transformations, viewing, lighting, texture mapping, shading, rendering, and animation.

**Recommended:** CS 261

## CS 551, COMPUTER GRAPHICS, 4 Credits

3-D graphics hardware: Line and polygon scan conversion, modeling transformations, viewing transformations, matrix stacks, hierarchical models, perspective and orthographic projections, visible surface determination, illumination models, shading models, texture mapping, ray tracing.

**Recommended:** CS 450 or CS 550

## CS 552, COMPUTER ANIMATION, 4 Credits

Traditional animation concepts: production pipeline, keyframing implementation, interpolation, point-mass dynamics, spring-mass systems, rigid body dynamics, forward and inverse kinematics, human motion control, motion capture.

**Recommended:** CS 551

## CS 553, SCIENTIFIC VISUALIZATION, 4 Credits

Applies 3D computer graphics methods to visually understand scientific and engineering data. Methods include hyperbolic projections; mapping scalar values to color spaces; data visualization using range sliders; scalar visualization (point clouds, cutting planes, contour plots, isosurfaces); vector visualization (arrow clouds, particle advection, streamlines); terrain visualization; Delauney triangulation; and volume visualization.

**Recommended:** Prior experience with Unix or Windows, programming experience.

## CS 554, GEOMETRIC MODELING IN COMPUTER GRAPHICS, 4 Credits

Advanced topics in computer graphics focusing on representation and processing of polygonal models and their application. Surface fundamentals; discrete differential geometry and topology; data structures for representing 3-D surfaces; surface subdivision and smoothing; mesh simplification and multi-resolution representation of 3-D surfaces; geometry compression; surface parameterization; geometry remeshing; topological simplification; implicit surfaces.

**Recommended:** CS 450

## CS 557, COMPUTER GRAPHICS SHADERS, 4 Credits

Theoretical and practical treatment of computer graphics shaders, including both RenderMan and GPU shaders. Programming in both RenderMan and OpenGL shading languages.

**Recommended:** Previous graphics pipeline programming experience.

## CS 559, SELECTED TOPICS IN COMPUTER GRAPHICS AND VISION, 0-5 Credits

Advanced topics in graphics, animation, and vision. Topics include distribution ray tracing, global-illumination, radiosity, image-based modeling and rendering, vision-assisted image and video editing, 3-D vision, 3-D virtual environments, 3-D interaction, control for physical simulation, motion graphs, computational geometry, etc.

*This course is repeatable for 99 credits.*

## CS 560, DATA-DRIVEN SOFTWARE ENGINEERING, 4 Credits

An overview of data-driven empirical research methods that can be used to understand the different aspects of software engineering.

**Prerequisite:** CS 561 with C or better

## CS 561, SOFTWARE ENGINEERING METHODS, 4 Credits

Master software engineering methods and supporting tools in the context of agile processes. Teams will engage in all aspects of software development including design, testing, implementation, deployment and maintenance. 3 hours of lecture per week plus one-hour independent lab per week.

**Recommended:** CS 362

## CS 562, SOFTWARE PROJECT MANAGEMENT, 4 Credits

Master software project management with an emphasis on timely, cost-effective delivery of high-quality systems. Learn about existing techniques and supporting tools, with a particular focus on coordination and project management. 3 hours of lecture per week plus one-hour independent lab per week.

**Recommended:** CS 561

## CS 563, SOFTWARE MAINTENANCE AND EVOLUTION, 4 Credits

Contribute to the cutting-edge of software engineering. Learn about existing techniques and supporting tools, with a particular focus on maintenance and evolution. Identify opportunities to support software maintenance and evolution more effectively, by creating new knowledge and supporting systems through research and innovation. 3 hours of lecture per week plus one-hour independent lab per week.

**Prerequisite:** CS 561 with C or better

## CS 564, FIELD STUDIES IN SE AND HCI, 4 Credits

Deals with the type of empirical study known as the 'case' study. These are studies that collect data from natural software development situations as they really occur in the field, in which the researcher does not manipulate or 'control' anything. The course is an end-to-end coverage of the process. Mainly focuses on case studies involving human software developers in the field. The student will conduct a field study as part of this course.

## CS 565, HUMAN-COMPUTER INTERACTION, 4 Credits

Basic principles of Human-Computer Interaction (HCI) for the design and evaluation of software systems. Includes research methods for studying human-machine interactions and user interfaces, design strategies, software evaluation methods, and related guidelines and standards.

## CS 567, LABORATORY STUDIES IN SE AND HCI, 4 Credits

Empirical lab studies of software development. Covers how to go about designing, preparing for, running, analyzing, and writing-for-publication lab experiments of programming situations involving human subjects. This is an end-to-end coverage of the entire process, and will put students in a position to conduct lab studies of their own with human subjects.

## CS 568, INCLUSIVE DESIGN (HCL), 4 Credits

Inclusive design is designing software that works for a wide variety of differently abled customers. Teaches the skills needed to design inclusively without having to have a separate design for each differently abled customer.

**Recommended:** CS 352 [C] or CS 565 [C]

## CS 569, SELECTED TOPICS IN SOFTWARE ENGINEERING, 0-5 Credits

Topics include new programming methodologies, productivity, software development, software complexity metrics.

*This course is repeatable for 99 credits.*

**Recommended:** CS 561

## CS 570, HIGH PERFORMANCE COMPUTER ARCHITECTURE, 4 Credits

Advanced concepts in computer architecture. Performance improvement employing advanced pipelining and multiple instruction scheduling techniques. Issues in memory hierarchy and management. CROSSLISTED as CS 570/ECE 570.

**Equivalent to:** ECE 570

**Recommended:** ECE 472 or ECE 572

## CS 572, COMPUTER ARCHITECTURE, 4 Credits

Computer architecture using processors, memories, and I/O devices as building blocks. Issues involved in the design of instruction set architecture, processor, pipelining and memory organization. Design philosophies and trade-offs involved in Reduced Instruction Set Computer (RISC) architectures. Lec/lab. CROSSLISTED as CS 472/ECE 472 and CS 572/ECE 572.

**Equivalent to:** ECE 572

**Recommended:** ECE 375

## CS 575, INTRODUCTION TO PARALLEL PROGRAMMING, 4 Credits

Theoretical and practical survey of parallel programming, including a discussion of parallel architecture, parallel programming paradigms, and parallel algorithms. Programming one or more parallel computers in a higher-level parallel language.

*Available via Ecampus*

## CS 576, ADVANCED COMPUTER NETWORKING, 4 Credits

Advanced networking concepts: source/channel coding, queuing theory, router design, network architectures (Intserv, DiffServ, MPLS), multimedia protocols (TFRC, RTP), overlay networks, and wireless standards (Bluetooth 802.11b, 3/4G). CROSSLISTED as CS 476/ECE 476 and CS 576/ECE 576.

**Equivalent to:** ECE 576

**Recommended:** (CS 372 or ECE 372) and (ECE 353 or ST 314 or ST 314H)

## CS 578, CYBER-SECURITY, 4 Credits

A broad overview of the field of computer and network security. Essential cryptographic mechanisms such as symmetric and public-key cryptography (e.g., encryption, signatures), network security and authentication protocols (e.g., Kerberos, TLS, IPSec), system security (e.g., access control, firewalls), advanced topics (e.g., searchable encryption, cloud security, secure computation). CROSSLISTED as CS 578/ECE 578.

**Equivalent to:** ECE 578

## CS 579, TOPICS IN COMPUTER ARCHITECTURE AND PARALLEL PROCESSING, 0-5 Credits

Current topics in advanced computer architecture and parallel processing.

*This course is repeatable for 99 credits.*

**Recommended:** CS 575 or CS 572 or ECE 572

## CS 581, PROGRAMMING LANGUAGES I, 4 Credits

Graduate-level introduction to functional programming and programming language theory. Strongly typed functional programming in Haskell, abstract syntax and grammars, interpreters, denotational semantics, domain theory, and lambda calculus.

## CS 582, PROGRAMMING LANGUAGES II, 4 Credits

Essentials of programming language theory for understanding and conducting programming language research. Dependently typed programming in Agda, Coq, or Idris; operational semantics; type systems; unification and type inference.

**Prerequisite:** CS 581 with C or better

## CS 583, ADVANCED FUNCTIONAL PROGRAMMING, 4 Credits

Advanced functional programming concepts and strategies, with a focus on techniques useful for the design and implementation of programming languages. Includes higher-order abstract syntax, functors and monads, generalized algebraic data types, functional data structures, and graph reduction.

**Prerequisite:** CS 581 with C or better

## CS 585, DOMAIN-SPECIFIC LANGUAGES, 4 Credits

Graduate-level introduction to the design and implementation of domain-specific languages (DSLs). Domain analysis; review and revision of language designs; binding constructs to support abstraction; definition of syntax and semantics of DSLs; prototype implementation of embedded DSL.

**Prerequisite:** CS 581 with C or better

## CS 589, SELECTED TOPICS IN PROGRAMMING LANGUAGES, 1-5 Credits

An in-depth examination of a specific topic of interest in programming language design and implementation. Example topics include object-oriented programming, parallel programming, compiler optimization, programming language semantics.

*This course is repeatable for 99 credits.*

## CS 599, SPECIAL TOPICS, 0-16 Credits

*This course is repeatable for 16 credits.*

## CS 601, RESEARCH, 1-16 Credits

Graded P/N.

*This course is repeatable for 99 credits.*

## CS 603, COMPUTER SCIENCE PHD THESIS, 1-16 Credits

*This course is repeatable for 999 credits.*

## CS 605, READING AND CONFERENCE, 1-16 Credits

*This course is repeatable for 16 credits.*

## CS 607, SEMINAR, 1-16 Credits

*This course is repeatable for 16 credits.*

## CS 637, COMPUTER VISION II, 4 Credits

An introduction to recent advances in visual recognition, including object detection, semantic segmentation, multimodal parsing of images and text, image captioning, face recognition, and human activity recognition.

The course covers common formulations of these problems, including energy minimization on graphical models, and supervised machine learning approaches to low- and high-level recognition tasks.

**Prerequisite:** CS 535 with B+ or better or CS 537 with B- or better

**Recommended:** CS 519

## Electrical and Computer Engineering (ECE)

### ECE 111, INTRODUCTION TO ECE: TOOLS, 3 Credits

Introduction to the electrical and computer engineering professional practice. Covers the foundations of engineering problem solving and other skills necessary for success. Students will be taught engineering practice through hands-on approaches. Recommended for electrical and computer engineering majors, and for those interested in engineering as a profession. Lec/lab. Has extra fees.

**Recommended:** Completion or concurrent enrollment in MTH 111

### ECE 112, INTRODUCTION TO ECE: CONCEPTS, 3 Credits

Basic electrical and computer engineering concepts, problem solving and hands-on laboratory project. Topics include electronic circuit and device models, digital logic, circuit analysis, and simulation tools. Lec/lab. Has extra fees.

**Prerequisite:** MTH 111 with C or better or MTH 112 with C or better or MTH 251 with C or better or MTH 251H with C or better or Math Placement Test with a score of 23

### ECE 199, SPECIAL STUDIES, 0-16 Credits

One-credit section. Graded P/N.

*This course is repeatable for 16 credits.*

### ECE 271, DIGITAL LOGIC DESIGN, 3 Credits

A first course in digital logic design. Data types and representations, Boolean algebra, state machines, simplification of switching expressions, and introductory computer arithmetic. Lec/rec.

**Prerequisite:** MTH 251 (may be taken concurrently) with C or better or MTH 251H (may be taken concurrently) with C or better or MTH 231 (may be taken concurrently) with C or better

### ECE 272, DIGITAL LOGIC DESIGN LABORATORY, 1 Credit

This laboratory course accompanies ECE 271, Digital Logic Design. This also illustrates topics covered in the lectures of ECE 271 using computer-aided design, verification tools, and prototyping hardware.

**Recommended:** Completion or concurrent enrollment in ECE 271

### ECE 322, ELECTRONICS I, 3 Credits

Fundamental device characteristics including diodes, MOSFETs and bipolar transistors; small- and large-signal characteristics and design of linear circuits.

**Prerequisite:** ENGR 203 with C or better

**Equivalent to:** ECE 322H



## ECE 322H, ELECTRONICS I, 3 Credits

Fundamental device characteristics including diodes, MOSFETs and bipolar transistors; small- and large-signal characteristics and design of linear circuits.

**Attributes:** HNRS – Honors Course Designator

**Prerequisite:** ENGR 203 with C or better

**Equivalent to:** ECE 322

## ECE 323, ELECTRONICS II, 3 Credits

Transient operation of MOSFETs and bipolar transistors; multistage amplifiers; frequency response; feedback and stability.

**Prerequisite:** ECE 322 with C or better

## ECE 331, ELECTROMECHANICAL ENERGY CONVERSION, 4 Credits

Energy conversion principles for electric machines. Steady state characteristics of direct current, induction, and synchronous machines. Application of stepper and servo motors and synchronous generators.

**Prerequisite:** (ENGR 202 with C or better or ENGR 202H with C or better) and MTH 256 [C] and PH 213 [C]

## ECE 332, LABORATORY ON ELECTROMECHANICAL ENERGY CONVERSION, 1 Credit

DC, PMAC, and induction machine testing, operation, and control.

**Prerequisite:** ENGR 202 with C or better or ENGR 202H with C or better

**Corequisites:** ECE 331

## ECE 341, JUNIOR DESIGN I, 3 Credits

Introduction to system design and group projects. Design and fabrication of an electrical engineering project in a small group.

**Prerequisite:** CS 261 (may be taken concurrently) with C or better and ENGR 203 [C]

## ECE 342, JUNIOR DESIGN II, 3 Credits

Introduction to system design and group projects. Design and fabrication of an electrical engineering project in a small group.

**Prerequisite:** ECE 341 with C or better

## ECE 351, SIGNALS AND SYSTEMS I, 3 Credits

Analytical techniques for continuous-time and discrete-time signal, system, and circuit analysis. Lec.

**Prerequisite:** ENGR 203 with C or better and (MTH 256 [C] or MTH 256H [C])

## ECE 352, SIGNALS AND SYSTEMS II, 3 Credits

Analytical techniques for continuous-time and discrete-time signal, system, and circuit analysis.

**Prerequisite:** ECE 351 with C or better and (MTH 306 [C] or MTH 306H [C])

## ECE 353, INTRODUCTION TO PROBABILITY AND RANDOM SIGNALS, 3 Credits

Explores discrete and continuous probability concepts, single and multiple random variable distributions, expectation, introductory stochastic processes, correlation and power spectral density properties of random signals, random signals through linear filters.

**Prerequisite:** ECE 351 with C or better

## ECE 372, INTRODUCTION TO COMPUTER NETWORKS, 4 Credits

Computer network principles, fundamental networking concepts, packet-switching and circuit switching, TCP/IP protocol layers, reliable data transfer, congestion control, flow control, packet forwarding and routing, MAC addressing, multiple access techniques. CROSSLISTED as CS 372/ ECE 372.

**Prerequisite:** CS 261 with C or better and (ECE 271 [C] or CS 271 [C])

**Equivalent to:** CS 372

**Recommended:** C programming and Unix familiarity.

## ECE 375, COMPUTER ORGANIZATION AND ASSEMBLY LANGUAGE PROGRAMMING, 4 Credits

Introduction to computer organization, how major components in a computer system function together in executing a program, and assembly language programming. Lec/lab.

**Prerequisite:** ECE 271 with C or better

**Recommended:** CS 261 or C/C++ programming

## ECE 390, ELECTRIC AND MAGNETIC FIELDS, 4 Credits

Static and quasi-static electric and magnetic fields.

**Prerequisite:** (MTH 255 with C or better or MTH 255H with C or better) and ENGR 203 (may be taken concurrently) [C] and PH 213 [C]

## ECE 391, TRANSMISSION LINES, 3 Credits

Transient and steady-state analysis of transmission line circuits with application to engineering problems.

**Prerequisite:** ECE 322 (may be taken concurrently) with C or better and ENGR 203 [C] and (MTH 254 [C] or MTH 254H [C]) and (MTH 256 [C] or MTH 256H [C])

**Equivalent to:** ECE 391X

## ECE 399, SPECIAL TOPICS, 1-16 Credits

Course work to meet students' needs in advanced or specialized areas and to introduce new, important topics in electrical and computer engineering at the undergraduate (junior/senior) level.

**Equivalent to:** ECE 399H

*This course is repeatable for 16 credits.*

## ECE 401, RESEARCH, 1-16 Credits

*This course is repeatable for 16 credits.*

## ECE 403, THESIS, 1-16 Credits

*This course is repeatable for 16 credits.*

## **ECE 405, READING AND CONFERENCE, 1-16 Credits**

*This course is repeatable for 16 credits.*

## **ECE 406, PROJECTS, 1-16 Credits**

*This course is repeatable for 16 credits.*

## **ECE 410, INTERNSHIP, 1-16 Credits**

*This course is repeatable for 16 credits.*

## **ECE 411, ENGINEERING MAGNETICS, 3 Credits**

Application of magnetic materials in the design of magnetic devices. Properties of magnetic materials; engineering design of actuators, sensors and data storage devices. Introduction to spintronics.

**Prerequisite:** ECE 390 with C or better

## **ECE 413, SENSORS, 3 Credits**

Overview of sensor technologies including materials, physics of operation, applications and system integration.

**Prerequisite:** ECE 323 with C or better and PH 213 [C] and (CH 201 [C] or CH 231 [C]) or (CH 121 [C] and CH 122 [C]) or (CH 231 [C] and CH 261 [C])

## **ECE 415, MATERIAL SCIENCE OF NANOTECHNOLOGY, 3 Credits**

Introductory physical chemistry of solid surfaces, thermodynamics, and kinetics applied to synthesis of nanomaterials such as nanoparticles, nanowires, thin films, carbon nanotubes, fullerenes, graphene, etc.

Characterization of nanomaterials, applications of nanomaterials, nanosynthesis techniques, integration of nanotechnology, and emerging nanotechnology topics.

**Prerequisite:** ECE 416 with C or better or ENGR 321 with C or better or ENGR 321H with C or better

## **ECE 416, ELECTRONIC MATERIALS AND DEVICES, 4 Credits**

Semiconductor fundamentals and physical principles of pn junctions and Schottky barrier diodes.

**Prerequisite:** ENGR 201 with C or better and PH 213 [C] and (CH 201 [C] or CH 231 [C]) or (CH 121 [C] and CH 122 [C]) or (CH 231 [C] and CH 261 [C])

**Equivalent to:** ECE 317

## **ECE 417, BASIC SEMICONDUCTOR DEVICES, 4 Credits**

Theory and physical principles of bipolar junction and field-effect transistors. Lec/rec.

**Prerequisite:** ECE 416 with C or better

## **ECE 418, SEMICONDUCTOR PROCESSING, 4 Credits**

Theory and practice of basic semiconductor processing techniques. Introduction to process simulation. Lec/lab/rec.

**Prerequisite:** ECE 416 with C or better

## **ECE 422, CMOS INTEGRATED CIRCUITS I, 4 Credits**

Analysis and design of analog integrated circuits in CMOS technology; current mirrors, gain stages, single-ended operational amplifier, frequency response, and compensation.

**Prerequisite:** ECE 322 with C or better and ECE 323 (may be taken concurrently) [C]

## **ECE 423, CMOS INTEGRATED CIRCUITS II, 4 Credits**

Analysis and design of analog integrated circuits in CMOS technology; cascaded current mirrors, cascaded gain stages, single-ended and fully differential operational amplifier, common-mode feedback, noise, and distortion. Lec/lab.

**Prerequisite:** ECE 422 with C or better

## **ECE 431, POWER ELECTRONICS, 4 Credits**

Fundamentals and applications of devices, circuits and controllers used in systems for electronic power processing. Lec/lab.

**Prerequisite:** ECE 322 with C or better and ECE 323 (may be taken concurrently) [C] and ECE 351 [C]

## **ECE 432, DYNAMICS OF ELECTROMECHANICAL ENERGY CONVERSION, 4 Credits**

Generalized machine theory. Techniques for dynamic analysis of electromechanical machines including arbitrary reference frame theory. Lec/lab.

**Prerequisite:** ECE 331 with C or better and ENGR 203 [C]

**Corequisites:** ECE 431

## **ECE 433, POWER SYSTEM ANALYSIS, 4 Credits**

Fundamentals and control of real and reactive power, steady-state load flow studies, unbalance, stability and transient system analysis.

**Prerequisite:** ECE 323 with C or better and ECE 352 [C] and (ENGR 202 [C] or ENGR 202H [C]) and MTH 254 [C] and MTH 306 [C]

**Recommended:** Three-phase power

## **ECE 437, SMART GRID, 3 Credits**

Fundamentals of smart power grids. Technology advances in transmission and distribution systems, policy drivers, assets and demand management, and smart grid security.

**Prerequisite:** ECE 433 with C or better

**Recommended:** Background in power systems analysis equivalent to ECE 433

## **ECE 438, ELECTRIC AND HYBRID ELECTRIC VEHICLES, 4 Credits**

Transportation electrification history, hybrid electric vehicle architecture, powertrain components and their modeling and control, vehicle system dynamics and controls.

**Prerequisite:** ECE 331 with C or better and ECE 431 [C]

## ECE 441, ^ENGINEERING DESIGN PROJECT, 3 Credits

Exposes problem situations and issues in engineering design similar to those encountered in industry through an extended team design project. (Writing Intensive Course)

**Attributes:** CWIC – Core, Skills, WIC

**Prerequisite:** ECE 342 with C or better and WR 327 [C]

## ECE 442, ^ENGINEERING DESIGN PROJECT, 3 Credits

Exposes problem situations and issues in engineering design similar to those encountered in industry through an extended team design project. (Writing Intensive Course)

**Attributes:** CWIC – Core, Skills, WIC

**Prerequisite:** ECE 441 with C or better

## ECE 443, ^ENGINEERING DESIGN PROJECT, 2 Credits

Exposes problem situations and issues in engineering design similar to those encountered in industry through an extended team design project. (Writing Intensive Course)

**Attributes:** CWIC – Core, Skills, WIC

**Prerequisite:** ECE 442 with C or better

## ECE 451, SYSTEMS DYNAMICS AND CONTROL, 4 Credits

Modeling and analysis of linear continuous systems in time and frequency domains. Fundamentals of single-input-single-output control system design. CROSSLISTED as ECE 451/ME 430.

**Prerequisite:** (ME 317 with C or better or ME 317H with C or better or (ECE 351 with C or better and ECE 352 [C] and (ENGR 212 [C] or ENGR 212H [C])))

**Equivalent to:** ME 430, ME 430H

*Available via Ecampus*

## ECE 461, INTRODUCTION TO ANALOG AND DIGITAL COMMUNICATIONS, 4 Credits

Fundamental concepts of analog and digital telecommunication systems: modeling, analysis, and design of analog amplitude and angle modulation systems; probabilistic performance assessment of modulated signals over noisy channels; introduction to baseband digital modulation techniques such as binary pulse amplitude modulation and pulse position modulation and their demodulation in the presence of random noise. Lec.

**Prerequisite:** ECE 351 with C or better and ECE 352 [C] and ECE 353 [C]

## ECE 462, DIGITAL COMMUNICATIONS AND CHANNEL CODING, 4 Credits

Modeling, analysis, design of baseband and passband digital communications systems: geometric representation of signals; correlator receivers for M-ary digital communications systems; decision theory and its application to digital communication systems in additive white Gaussian noise environment; generation, transmission, and reception of passband digital modulated signals (BPSK, QPSK, FSK PAM); basics of information theory and channel encoding. Lec.

**Prerequisite:** ECE 461 with C or better and ECE 351 [C] and ECE 352 [C] and ECE 353 [C]

## ECE 463, WIRELESS COMMUNICATIONS NETWORK, 4 Credits

Wireless networks: personal area (IEEE 802.15.4a), local area (IEEE 802.11), metropolitan area (IEEE 802.16), and mobile cellular networks (e.g., CDMA); physical-layer techniques for data modulation and multiple access; RF system engineering aspects of mobile cellular networks (e.g., system capability for voice and packet data traffics, RF coverage for a certain propagation environment.) Lec.

**Prerequisite:** ECE 351 with C or better and ECE 352 [C]

**Recommended:** Probability background and ECE 461

## ECE 464, DIGITAL SIGNAL PROCESSING, 4 Credits

Analysis and design of discrete-time linear-time invariant systems for processing discrete-time signals: DT-LTI system properties, DT signal analysis using Discrete-Time Fourier Transform, Discrete Fourier Transform and z-Transform, frequency response and transfer function. Signal sampling and reconstruction, digital processing of continuous-time signals, FIR and IIR digital filter design, and filter structures.

**Prerequisite:** ECE 351 with C or better and ECE 352 [C]

## ECE 468, DIGITAL IMAGE PROCESSING, 3 Credits

Introduction to digital image processing including fundamental concepts of visual perception, image sampling and quantization, image enhancement in spatial and frequency domains (through 2D Fourier transform), image restoration, and color image processing. Implementation of algorithms using Matlab Image Processing Toolbox.

**Prerequisite:** ECE 351 with C or better and ECE 352 [C]

## ECE 471, ENERGY-EFFICIENT VLSI DESIGN, 4 Credits

Combinational and sequential logic design using CMOS transistors; analysis of power consumption and logic delay of digital logic; clock design including skew, jitter, and dynamic clock energy consumption; supply voltage and power supply noise sources; dynamic voltage frequency scaling (DVFS); sub-threshold logic design and effect on energy/robustness; custom digital integrated circuit design including transistor layouts and CAD entry; CMOS scaling and the effect on process variability and power consumption. Lec/lab.

**Prerequisite:** ECE 271 with C or better and ECE 322 [C] and ECE 323 (may be taken concurrently) [C]

## ECE 472, COMPUTER ARCHITECTURE, 4 Credits

Computer architecture using processors, memories, and I/O devices as building blocks. Issues involved in the design of instruction set architecture, processor, pipelining and memory organization. Design philosophies and trade-offs involved in Reduced Instruction Set Computer (RISC) architectures. Lec/lab. CROSSLISTED as CS 472/ECE 472 and CS 572/ECE 572.

**Prerequisite:** ECE 375 with C or better

**Equivalent to:** CS 472

## **ECE 473, MICROCONTROLLER SYSTEM DESIGN, 4 Credits**

Implementation of embedded computer systems focusing on the development of hardware and software for an embedded microcontroller system. Topics include internal microcontroller architecture, interfacing peripheral devices, mixed analog and digital systems, and hardware and software implementation of several systems using a microcontroller and peripherals. Lec/lab.

**Prerequisite:** ECE 322 with C or better and ECE 375 [C] and CS 261 [C]

## **ECE 474, VLSI SYSTEM DESIGN, 4 Credits**

Introduction to custom and semi-custom digital integrated circuit design as used in VLSI systems. The use of CAD/CAE tools, design management, and design methodology are introduced.

**Prerequisite:** ECE 322 with C or better and ECE 375 [C]

## **ECE 476, ADVANCED COMPUTER NETWORKING, 4 Credits**

Advanced networking concepts: source/channel coding, queuing theory, router design, network architectures (Intserv, DiffServ, MPLS), multimedia protocols (TFRC, RTP), overlay networks, and wireless standards (Bluetooth 802.11b, 3/4G). CROSSLISTED as CS 476/ECE 476 and CS 576/ECE 576.

**Prerequisite:** (CS 372 with C or better or ECE 372 with C or better) and (ECE 353 [C] or ST 314 [C] or ST 314H [C])

**Equivalent to:** CS 476, EECS 476

## **ECE 477, MULTIMEDIA SYSTEMS, 4 Credits**

Design of multimedia systems used in information technology covering the hardware, software, applications, and networks. Components covered include multimedia representation, coding and compression techniques, wireless networks, networking for multimedia, and embedded system for multimedia. Lec.

**Recommended:** ECE 375

## **ECE 478, NETWORK SECURITY, 4 Credits**

Basic concepts and techniques in network security, risks and vulnerabilities, applied cryptography and various network security protocols. Coverage of high-level concepts such as authentication, confidentiality, integrity, and availability applied to networking systems. Fundamental techniques including authentication protocols, group key establishment and management, trusted intermediaries, public key infrastructures, SSL/TLS, IPSec, firewalls and intrusion detection CROSSLISTED as CS 478/ECE 478.

**Prerequisite:** CS 372 with C or better or ECE 372 with C or better

**Equivalent to:** CS 478

**Recommended:** CS 370

## **ECE 482, OPTICAL ELECTRONIC SYSTEMS, 4 Credits**

Photodetectors, laser theory, and laser systems. Lec/lab. CROSSLISTED as ECE 482/PH 482 and ECE 582/PH 582.

**Equivalent to:** PH 482

**Recommended:** ECE 391 or (PH 481 or PH 581)

## **ECE 483, GUIDED WAVE OPTICS, 4 Credits**

Optical fibers, fiber mode structure and polarization effects, fiber interferometry, fiber sensors, optical communication systems. Lec/lab. CROSSLISTED as ECE 483/PH 483 and ECE 583/PH 583.

**Prerequisite:** ECE 391 (may be taken concurrently) with C or better or PH 481 (may be taken concurrently) with C or better

**Equivalent to:** PH 483

## **ECE 484, ANTENNAS AND PROPAGATION, 4 Credits**

Introduction to antennas and radiowave propagation. Offered alternate years.

**Prerequisite:** (ECE 390 with C or better and ECE 391 [C])

## **ECE 485, MICROWAVE DESIGN TECHNIQUES, 4 Credits**

Introduction to basic design techniques required for the design of high-frequency circuits and systems. Lec/Lab.

**Prerequisite:** ECE 390 with C or better and ECE 391 [C]

## **ECE 499, SPECIAL TOPICS, 0-16 Credits**

Course work to meet students' needs in advanced or specialized areas and to introduce new important topics in electrical and computer engineering at the undergraduate level.

*This course is repeatable for 16 credits.*

## **ECE 501, RESEARCH, 1-16 Credits**

*This course is repeatable for 16 credits.*

## **ECE 503, ECE MS THESIS, 1-16 Credits**

*This course is repeatable for 999 credits.*

## **ECE 505, READING AND CONFERENCE, 1-16 Credits**

*This course is repeatable for 16 credits.*

## **ECE 506, PROJECTS, 1-16 Credits**

*This course is repeatable for 16 credits.*

## **ECE 507, SEMINAR, 1-16 Credits**

Graded P/N.

*This course is repeatable for 16 credits.*

## **ECE 510, OCCUPATIONAL INTERNSHIP, 1-4 Credits**

*This course is repeatable for 99 credits.*

*Available via Ecampus*

## **ECE 516, ELECTRONIC MATERIALS AND DEVICES, 4 Credits**

Semiconductor fundamentals and physical principles of pn junctions and Schottky barrier diodes.

**Equivalent to:** ECE 317

**Recommended:** ENGR 201



## **ECE 517, BASIC SEMICONDUCTOR DEVICES, 4 Credits**

Theory and physical principles of bipolar junction and field-effect transistors. Lec/rec.

**Recommended:** ECE 416

## **ECE 518, SEMICONDUCTOR PROCESSING, 4 Credits**

Theory and practice of basic semiconductor processing techniques. Introduction to process simulation. Lec/lab/rec.

**Recommended:** ECE 416

## **ECE 520, ANALOG CMOS INTEGRATED CIRCUITS, 4 Credits**

Principles and techniques of design of electronic circuits with focus on a design methodology for analog integrated circuits. Practical aspects of using CAD tools in analyzing and laying out circuits will be discussed.

## **ECE 521, ANALOG CIRCUIT SIMULATION, 4 Credits**

Formulation/solution of circuit equations; sparse matrix techniques; DC, transient, sensitivity, noise and Fourier analyses; RF circuit simulation.

**Recommended:** ECE 423 or ECE 520

## **ECE 522, CMOS INTEGRATED CIRCUITS I, 4 Credits**

Analysis and design of analog integrated circuits in CMOS technology; current mirrors, gain stages, single-ended operational amplifier, frequency response, and compensation.

**Recommended:** ECE 322 and completion or concurrent enrollment in ECE 323

## **ECE 523, CMOS INTEGRATED CIRCUITS II, 4 Credits**

Analysis and design of analog integrated circuits in CMOS technology; cascaded current mirrors, cascaded gain stages, single-ended and fully differential operational amplifier, common-mode feedback, noise, and distortion. Lec/lab.

**Recommended:** ECE 422 or ECE 522

## **ECE 530, CONTEMPORARY ENERGY APPLICATIONS, 4 Credits**

Contemporary energy issues and applications; fundamental physics of renewable energy sources (e.g. wind, wave, and solar), devices used to harvest energy from these sources, state-of-the-art renewable energy technology, power transmission, transformers, and energy storage.

**Recommended:** Matlab, basic circuit analysis with RLC components and diode

## **ECE 531, POWER ELECTRONICS, 4 Credits**

Fundamentals and applications of devices, circuits and controllers used in systems for electronic power processing. Lec/lab.

**Recommended:** ECE 322 and ECE 351 and completion or concurrent enrollment in ECE 323

## **ECE 532, DYNAMICS OF ELECTROMECHANICAL ENERGY CONVERSION, 4 Credits**

Generalized machine theory. Techniques for dynamic analysis of electromechanical machines including arbitrary reference frame theory. Lec/lab.

**Corequisites:** ECE 531

**Recommended:** ECE 331

## **ECE 533, POWER SYSTEM ANALYSIS, 4 Credits**

Fundamentals and control of real and reactive power, steady-state load flow studies, unbalance, stability and transient system analysis.

**Recommended:** ECE 323 and ECE 352 and three-phase power

## **ECE 535, ADJUSTABLE SPEED DRIVES AND MOTION CONTROL, 3 Credits**

Adjustable speed drives, associated power electronic converters, simulation and control. Lec.

**Equivalent to:** ECE 647

**Recommended:** ECE 530

## **ECE 536, POWER SYSTEM PROTECTION, 3 Credits**

Fundamentals of protective relaying. Relay input sources. Generation, transmission, and distribution systems protection. Stability and load shedding.

**Recommended:** ECE 433 or ECE 533

## **ECE 537, SMART GRID, 3 Credits**

Fundamentals of smart power grids. Technology advances in transmission and distribution systems, policy drivers, assets and demand management, and smart grid security.

**Recommended:** Background in power systems analysis equivalent to ECE 433

## **ECE 538, ELECTRIC AND HYBRID ELECTRIC VEHICLES, 4 Credits**

Transportation electrification history, hybrid electric vehicle architecture, powertrain components and their modeling and control, vehicle system dynamics and controls.

**Equivalent to:** ECE 534

**Recommended:** ECE 331 and ECE 431

## **ECE 550, LINEAR SYSTEMS, 4 Credits**

Linear dynamic systems theory and modeling.

**Recommended:** ECE 351 and ECE 352

## **ECE 560, STOCHASTIC SIGNALS AND SYSTEMS, 4 Credits**

Stochastic processes, correlation functions, spectral analysis applicable to communication and control systems.

**Recommended:** ECE 461 or ECE 561

## ECE 561, INTRODUCTION TO ANALOG AND DIGITAL COMMUNICATIONS, 4 Credits

Fundamental concepts of analog and digital telecommunication systems: modeling, analysis, and design of analog amplitude and angle modulation systems; probabilistic performance assessment of modulated signals over noisy channels; introduction to baseband digital modulation techniques such as binary pulse amplitude modulation and pulse position modulation and their demodulation in the presence of random noise. Lec.

**Recommended:** ECE 351 and ECE 352 and ECE 353

## ECE 562, DIGITAL COMMUNICATIONS AND CHANNEL CODING, 4 Credits

Modeling, analysis, design of baseband and passband digital communications systems: geometric representation of signals; correlator receivers for M-ary digital communications systems; decision theory and its application to digital communication systems in additive white Gaussian noise environment; generation, transmission, and reception of passband digital modulated signals (BPSK, QPSK, FSK PAM); basics of information theory and channel encoding. Lec.

**Recommended:** ECE 461 and ECE 351 and ECE 352 and ECE 353

## ECE 563, WIRELESS COMMUNICATIONS NETWORK, 4 Credits

Wireless networks: personal area (IEEE 802.15.4a), local area (IEEE 802.11), metropolitan area (IEEE 802.16), and mobile cellular networks (e.g., CDMA); physical-layer techniques for data modulation and multiple access; RF system engineering aspects of mobile cellular networks (e.g., system capability for voice and packet data traffics, RF coverage for a certain propagation environment.) Lec.

**Recommended:** Probability background and ECE 461

## ECE 564, DIGITAL SIGNAL PROCESSING, 4 Credits

Analysis and design of discrete-time linear-time invariant systems for processing discrete-time signals: DT-LTI system properties, DT signal analysis using Discrete-Time Fourier Transform, Discrete Fourier Transform and z-Transform, frequency response and transfer function. Signal sampling and reconstruction, digital processing of continuous-time signals, FIR and IIR digital filter design, and filter structures.

**Recommended:** ECE 351 and ECE 352

## ECE 565, ESTIMATION, FILTERING, AND DETECTION, 4 Credits

Principles of estimation, linear filtering, and detection.

**Recommended:** ECE 353

## ECE 566, INFORMATION THEORY, 4 Credits

Introduction to information theory: entropy, differential entropy, entropy rates, mutual information, data compression, channel capacity, source coding, channel coding, network information theory.

**Recommended:** ECE 353 and strong mathematical background

## ECE 569, CONVEX OPTIMIZATION, 4 Credits

Introduces the fundamental concepts, theories of convex and nonconvex optimization, and the algorithmic solutions as well as applications to many research disciplines including signal processing, networking, communications, and machine learning. Emphasis will be on (i) convex analysis and optimality conditions, (ii) first-order large-scale algorithms (gradient, proximal gradient, ADMM, Frank-Wolfe, stochastic gradient, block coordinate descent), and (iii) convergence analysis.

**Recommended:** Linear algebra and ECE 599 Matrix Analysis for Signal Processing

## ECE 570, HIGH PERFORMANCE COMPUTER ARCHITECTURE, 4 Credits

Advanced concepts in computer architecture. Performance improvement employing advanced pipelining and multiple instruction scheduling techniques. Issues in memory hierarchy and management. CROSSLISTED as CS 570/ECE 570.

**Equivalent to:** CS 570

**Recommended:** ECE 472 or ECE 572

## ECE 571, ENERGY-EFFICIENT VLSI DESIGN, 4 Credits

Combinational and sequential logic design using CMOS transistors; analysis of power consumption and logic delay of digital logic; clock design including skew, jitter, and dynamic clock energy consumption; supply voltage and power supply noise sources; dynamic voltage frequency and scaling (DVFS); sub-threshold logic design and effect on energy/robustness; custom digital integrated circuit design including transistor layouts and CAD entry; CMOS scaling and the effect on process variability and power consumption. Lec/lab.

**Equivalent to:** ECE 573

**Recommended:** ECE 271 and ECE 322 and completion or concurrent enrollment in ECE 323 (all with a minimum grade of C)

## ECE 572, COMPUTER ARCHITECTURE, 4 Credits

Computer architecture using processors, memories, and I/O devices as building blocks. Issues involved in the design of instruction set architecture, processor, pipelining and memory organization. Design philosophies and trade-offs involved in Reduced Instruction Set Computer (RISC) architectures. Lec/lab. CROSSLISTED as CS 472/ECE 472 and CS 572/ECE 572.

**Equivalent to:** CS 572

**Recommended:** ECE 375

## ECE 573, MICROCONTROLLER SYSTEM DESIGN, 4 Credits

Implementation of embedded computer systems focusing on the development of hardware and software for an embedded microcontroller system. Topics include internal microcontroller architecture, interfacing peripheral devices, mixed analog and digital systems, and hardware and software implementation of several systems using a microcontroller and peripherals. Lec/lab.

**Equivalent to:** ECE 571

**Recommended:** ECE 322 and ECE 375 and CS 261

## ECE 574, VLSI SYSTEM DESIGN, 4 Credits

Introduction to custom and semi-custom digital integrated circuit design as used in VLSI systems. The use of CAD/CAE tools, design management, and design methodology are introduced.

**Recommended:** ECE 322 or ECE 375

## ECE 576, ADVANCED COMPUTER NETWORKING, 4 Credits

Advanced networking concepts: source/channel coding, queuing theory, router design, network architectures (Intserv, DiffServ, MPLS), multimedia protocols (TFRC, RTP), overlay networks, and wireless standards (Bluetooth 802.11b, 3/4G). CROSSLISTED as CS 476/ECE 476 and CS 576/ECE 576.

**Equivalent to:** CS 576, ECE 566

**Recommended:** (CS 372 or ECE 372) and (ECE 353 or ST 314 or ST 314H)

## ECE 577, MULTIMEDIA SYSTEMS, 4 Credits

Design of multimedia systems for information technology covering the hardware, software, applications, and networks. Components covered include multimedia representation, coding and compression techniques, wireless networks, networking for multimedia, and embedded system for multimedia. Lec.

**Recommended:** ECE 375

## ECE 578, CYBER-SECURITY, 4 Credits

A broad overview of the field of computer and network security. Essential cryptographic mechanisms such as symmetric and public-key cryptography (e.g., encryption, signatures), network security and authentication protocols (e.g., Kerberos, TLS, IPSec), system security (e.g., access control, firewalls), advanced topics (e.g., searchable encryption, cloud security, secure computation). CROSSLISTED as CS 578/ECE 578.

**Equivalent to:** CS 578

## ECE 580, NETWORK THEORY, 4 Credits

Linear graphs, multiport networks, and other topics in advanced network theory.

## ECE 582, OPTICAL ELECTRONIC SYSTEMS, 4 Credits

Photodetectors, laser theory, and laser systems. Lec/lab. CROSSLISTED as ECE 482/PH 482 and ECE 582/PH 582.

**Equivalent to:** PH 582

**Recommended:** PH 481 or PH 581

## ECE 583, GUIDED WAVE OPTICS, 4 Credits

Optical fibers, fiber mode structure and polarization effects, fiber interferometry, fiber sensors, optical communication systems. Lec/lab. CROSSLISTED as ECE 483/PH 483 and ECE 583/PH 583.

**Equivalent to:** PH 583

**Recommended:** Completion or concurrent enrollment in (ECE 391 or PH 481 or PH 581)

## ECE 584, ANTENNAS AND PROPAGATION, 4 Credits

Introduction to antennas and radiowave propagation. Offered alternate years.

## ECE 585, MICROWAVE DESIGN TECHNIQUES, 4 Credits

Introduction to basic design techniques required for the design of high-frequency circuits and systems. Lec/Lab.

## ECE 590, ANALYTICAL TECHNIQUES IN ELECTROMAGNETIC FIELDS, 4 Credits

Basic analytical techniques required to solve meaningful field problems in engineering.

## ECE 591, ADVANCED ELECTROMAGNETICS, 3 Credits

Advanced techniques for analyzing problems in electromagnetics, primarily numerical. Offered alternate years.

**Recommended:** ECE 590

## ECE 593, RF MICROWAVE CIRCUIT DESIGN, 3 Credits

Active/passive RF and microwave circuit design with emphasis to wireless systems.

**Recommended:** ECE 390 and ECE 391

## ECE 599, SPECIAL TOPICS, 0-16 Credits

Course work to meet students' needs in advanced or specialized areas and to introduce new important topics in electrical and computer engineering at the graduate level.

*This course is repeatable for 99 credits.*

## ECE 601, RESEARCH, 1-16 Credits

*This course is repeatable for 16 credits.*

## ECE 603, ECE PhD THESIS, 1-16 Credits

*This course is repeatable for 999 credits.*

## ECE 605, READING AND CONFERENCE, 1-16 Credits

*This course is repeatable for 16 credits.*

## ECE 606, PROJECTS, 1-16 Credits

*This course is repeatable for 16 credits.*

## ECE 607, SEMINAR, 1-16 Credits

*This course is repeatable for 16 credits.*

## ECE 611, ELECTRONIC MATERIALS PROCESSING, 3 Credits

Technology, theory, and analysis of processing methods used in integration circuit fabrication. Offered alternate years. CROSSLISTED as CHE 611/ECE 611.

**Equivalent to:** CHE 611, ECE 511

## ECE 612, PROCESS INTEGRATION, 3 Credits

Process integration, simulation, and statistical quality control issues related to integrated circuit fabrication. Offered alternate years.

CROSSLISTED as CHE 612/ECE 612.

**Equivalent to:** CHE 612, ECE 512

**Recommended:** ECE 611 or CHE 611

## **ECE 613, ELECTRONIC MATERIALS AND CHARACTERIZATION, 3 Credits**

Physics and chemistry of electronic materials and methods of materials characterization. Offered alternate years. CROSSLISTED as CHE 613/ ECE 613.

**Equivalent to:** CHE 613, ECE 513

## **ECE 614, SEMICONDUCTORS, 3 Credits**

Essential aspects of semiconductor physics relevant for an advanced understanding of semiconductor materials and devices. Offered alternate years.

**Equivalent to:** ECE 514

**Recommended:** Exposure to quantum mechanics and solid state physics.

## **ECE 615, SEMICONDUCTOR DEVICES I, 3 Credits**

Advanced treatment of two-terminal semiconductor electronic devices. Offered alternate years.

**Equivalent to:** ECE 515

**Recommended:** ECE 614

## **ECE 616, SEMICONDUCTOR DEVICES II, 3 Credits**

Advanced treatment of three-terminal semiconductor electronic devices. Offered alternate years.

**Equivalent to:** ECE 516

**Recommended:** ECE 615

## **ECE 617, THIN FILM TRANSISTORS, 4 Credits**

Thin-film electronics typically necessitate semiconducting materials lacking long-range order (disordered semiconductors), and hence provide a range of challenges and opportunities for device engineers. Provides a comprehensive review of the device physics and materials science of thin film electronics – in particular thin-film transistors. Provides students with the theoretical and practical knowledge to be successful in the development and study of thin film transistors, in both academic and industrial environments.

**Recommended:** ECE 390, ECE 416/ECE516, ECE 417/ECE 517, ECE 614

## **ECE 619, SELECTED TOPICS IN SOLID STATE, 3 Credits**

Special courses taught on various topics in solid state as interests and demands vary.

*This course is repeatable for 99 credits.*

## **ECE 621, RADIO FREQUENCY IC DESIGN, 3 Credits**

Radio frequency (RF) circuits. Principles, analysis, and design of bipolar and MOS RF IC building blocks: low noise amplifiers, mixers, oscillators, frequency synthesizers.

**Recommended:** (ECE 422 or ECE 522) and (ECE 423 or ECE 523) or ECE 520

## **ECE 626, ANALOG CMOS CIRCUIT DESIGN, 3 Credits**

Switched-capacitor circuit design, on-chip filters, data converters. Practical aspects of analog CMOS IC design.

## **ECE 627, OVERSAMPLED DELTA-SIGMA DATA CONVERTERS, 3 Credits**

Noise-shaping theory in first, second, and higher-order modulators. Design, simulation, and realization in hardware of converters using this popular architecture.

## **ECE 629, SELECTED TOPICS IN MICROELECTRONICS, 3 Credits**

Course work to meet student's needs in advanced or specialized areas and to introduce the newest important results in microelectronics.

## **ECE 659, SELECTED TOPICS IN SYSTEMS AND CONTROL, 3 Credits**

Course work to meet students' needs in advanced or specialized areas and to introduce the newest important results in systems and control.

*This course is repeatable for 18 credits.*

## **ECE 669, SELECTED TOPICS IN COMMUNICATIONS AND SIGNAL PROCESSING, 3 Credits**

Course work to meet students' needs in advanced or specialized areas and to introduce the newest important results in signal processing.

*This course is repeatable for 18 credits.*

## **ECE 679, SELECTED TOPICS IN COMPUTER ENGINEERING, 1-16 Credits**

Topics to be presented at various times include information storage and retrieval, computer architecture, fault-tolerant computing, asynchronous sequential circuits, automata, data transmission, coding theory.

*This course is repeatable for 99 credits.*

## **ECE 699, SPECIAL TOPICS, 3 Credits**

Advanced studies in field and wave theories and special devices. Topic examples are microwave and acoustic devices, advanced lasers and masers, electron beam interactions with traveling waves, MHD device dynamics.

*This course is repeatable for 99 credits.*

## **Humanitarian Engineering Science and Technology (HEST)**

### **HEST 199, SPECIAL TOPICS, 1-6 Credits**

*This course is repeatable for 9 credits.*

### **HEST 201, INNOVATION FOR SOCIAL IMPACT, 3 Credits**

Introduces methods for designing solutions to address needs of low-resource or other vulnerable peoples using tools from engineering and social sciences, and investigates techniques to bring ideas to market sustainably through social entrepreneurship. Multidisciplinary teams will step through the design process, including detailed needs assessment and customer discovery, critique and application of theoretical frameworks, exploration of the diffusion process and relevant system/institutions, prototyping, plans for technical and user experience testing, and considering implementation. CROSSLISTED as ANTH 201/ HEST 201.

**Equivalent to:** ANTH 201



## HEST 241, HOUSEHOLD ENERGY IN GUATEMALA: BACKGROUND, 1 Credit

An introduction to the technical, social, environmental, and economic issues surrounding energy needs for households in developing countries and the technologies and policies needed to help address them. Students are introduced to concepts about global development, needs assessment and co-design, qualitative and quantitative evaluation, and local socioeconomic conditions. This course is preparation for the 10-day Summer HEST 242 faculty-led study abroad course in Guatemala. Students from any major are invited to participate in this multidisciplinary course series.

## HEST 242, HOUSEHOLD ENERGY IN GUATEMALA: APPLICATIONS, 3 Credits

Through immersion in rural communities during this 10-day interdisciplinary study abroad course, students will gain a deeper understanding of household energy needs in developing countries, as well as the social, environmental, technical, and economic issues surrounding technologies and policies to help meet these needs. The outcomes produced by a variety of household technologies such as biomass cookstoves will be evaluated through qualitative and quantitative data gathering, including experiments, observations, and surveys, giving students the chance to practice their research and cross-cultural communication skills under a variety of circumstances.

**Recommended:** HEST 241

## HEST 299, SPECIAL TOPICS, 1-6 Credits

*This course is repeatable for 9 credits.*

## HEST 310, \*INTRO TO COMMUNITY ENGAGEMENT AND COMMUNITY-BASED DESIGN, 3 Credits

Includes study of civic problems and issues, design-thinking concepts and application to co-design of engineering, science and technology-based solutions with social impact, and development of dispositions for effective community engagement through field study and service-learning. Recommended course for student wanting to complete a HEST internship. (Bacc Core Course)

**Attributes:** CSST – Core, Synthesis, Science/Technology/Society

## HEST 320, \*ENGINEERING FOR GLOBAL HEALTH SOLUTIONS, 3 Credits

An introduction to the critical processes and drivers involved in the development of engineering solutions to address global health problems. Topics include world health challenges, accessing and interpreting health and economic data, basic healthcare systems around the world, the importance of ethical guidelines in ensuring the protection of human subjects, the process of cost effectiveness assessment of a technology, and the timescale and hurdles to adoption of a technology. (Bacc Core Course)

**Attributes:** CSST – Core, Synthesis, Science/Technology/Society

## HEST 399, SPECIAL TOPICS, 1-6 Credits

*This course is repeatable for 9 credits.*

## HEST 411, ENGINEERING DESIGN FOR EMERGENCY & LOW-RESOURCE ENVIRONMENTS, 3 Credits

Introduces the challenges of engineering in emergency and low-resource environments, concepts of appropriate technologies and response, and engineering design of discrete services and technologies such as water systems, environmental health systems and infrastructure.

**Recommended:** Completion of an undergraduate engineering fluid mechanics course

## HEST 412, \*MULTIDISCIPLINARY CASE STUDIES IN HUMANITARIAN ENGINEERING, SCIENCE AND TECHNOLOGY, 3 Credits

Introduces students to multidisciplinary methods and perspectives applied to case studies in humanitarian engineering, science and technology. Applications to real world issues with global implications at the interface of humanity and nature are addressed from a systems perspective using a case study approach.

**Attributes:** CSST – Core, Synthesis, Science/Technology/Society  
*Available via Ecampus*

## HEST 415, UAV ENGINEERING, 4 Credits

Develop a strong foundation in Unmanned Aerial Vehicles (UAV) systems technologies. Engineering evaluation of UAV systems, subcomponents, aircraft missions, operations and Federal Aviation Administration (FAA) requirements. Apply actual UAV models and subsystems to a real-world project on UAV deployment for humanitarian and environmental missions. Write a technical report as a team-project, developing and demonstrating critical thinking and engineering reporting skills in the subject. CROSSLISTED as AAE 415/HEST 415.

**Prerequisite:** ME 316 with C or better and ME 317 [C] and ME 331 [C] and ME 373 [C]

**Equivalent to:** AAE 415

## HEST 499, SPECIAL TOPICS, 1-6 Credits

*This course is repeatable for 9 credits.*

## HEST 511, ENGINEERING DESIGN FOR EMERGENCY & LOW-RESOURCE ENVIRONMENTS, 3 Credits

Introduces the challenges of engineering in emergency and low-resource environments, concepts of appropriate technologies and response, and engineering design of discrete services and technologies such as water systems, environmental health systems and infrastructure.

**Recommended:** Completion of an undergraduate engineering fluid mechanics course

## **HEST 512, MULTIDISCIPLINARY CASE STUDIES IN HUMANITARIAN ENGINEERING, SCIENCE AND TECHNOLOGY, 3 Credits**

Introduces students to multidisciplinary methods and perspectives applied to case studies in humanitarian engineering, science and technology. Applications to real world issues with global implications at the interface of humanity and nature are addressed from a systems perspective using a case study approach.

*Available via Ecampus*

## **HEST 541, HOUSEHOLD ENERGY IN GUATEMALA: BACKGROUND, 1 Credit**

An introduction to the technical, social, environmental, and economic issues surrounding energy needs for households in developing countries and the technologies and policies needed to help address them.

Students are introduced to concepts about global development, needs assessment and co-design, qualitative and quantitative evaluation, and local socioeconomic conditions. This course is preparation for the 10-day Summer HEST 542 faculty-led study abroad course in Guatemala. Students from any major are invited to participate in this multidisciplinary course series.

## **HEST 542, HOUSEHOLD ENERGY IN GUATEMALA: APPLICATIONS, 3 Credits**

Through immersion in rural communities during this 10-day interdisciplinary study abroad course, students will gain a deeper understanding of household energy needs in developing countries, as well as the social, environmental, technical, and economic issues surrounding technologies and policies to help meet these needs. The outcomes produced by a variety of household technologies such as biomass cookstoves will be evaluated through qualitative and quantitative data gathering, including experiments, observations, and surveys, giving students the chance to practice their research and cross-cultural communication skills under a variety of circumstances.

**Recommended:** HEST 541

## **HEST 599, SPECIAL TOPICS, 1-6 Credits**

*This course is repeatable for 9 credits.*

### **Software Engineering (SE)**

## **SE 199, SPECIAL TOPICS, 0-16 Credits**

*This course is repeatable for 16 credits.*

## **SE 201, SOFTWARE DEVELOPMENT I, 4 Credits**

Introduction to collaborative software development of larger, object-oriented systems. Overview of software architecture, and the tools, principles and practice of modern software development.

**Prerequisite:** CS 162 with C or better

## **SE 299, SPECIAL TOPICS, 0-16 Credits**

*This course is repeatable for 16 credits.*

## **SE 303, SOFTWARE ENGINEERING III, 4 Credits**

Introduction to refactoring techniques and improving the quality and maintainability of software. Applying continuous integration and deployment tools; containers and virtual development environments.

**Prerequisite:** CS 362 with C or better

## **SE 399, SPECIAL TOPICS, 0-16 Credits**

*This course is repeatable for 16 credits.*

## **SE 467, BUSINESS OF SOFTWARE II, 4 Credits**

Become an entrepreneur. Start a real software business, from ideation to sales. Real-world, hands-on learning in a fast-paced startup environment. Development of product ideas, hypotheses, and business models to discover customers. Teamwork, management, and positioning for investment.

**Prerequisite:** CS 466 with C or better

## **SE 468, BUSINESS OF SOFTWARE III, 4 Credits**

Become an entrepreneur. Start a real software business, from ideation to sales. Real-world, hands-on learning in a fast-paced startup environment. Development of product ideas, hypotheses, and business models to discover customers. Teamwork, management, and positioning for investment.

**Prerequisite:** SE 467 with C or better

## **SE 499, SPECIAL TOPICS, 0-16 Credits**

*This course is repeatable for 16 credits.*