

Computer Engineering Undergraduate Handbook

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Computer Engineering Program
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The School of Computing and the Department of Electrical and Computer Engineering jointly offer a Bachelor of Science degree in Computer Engineering. Accredited by ABET in 1998, the program begins with a pair of two-course sequences. One sequence consists of introductory computer science classes that give students solid programming skills while exposing them to the breadth of issues that arise in computer science. The other consists of introductory electrical engineering classes that cover the basics of analog and digital circuits, along with laboratory instruction on the proper use of electronic measuring instruments.

Students then take eight core courses in electric circuits, electronics, digital system design, computer architecture, software engineering, systems software, computer design, and microprocessor interfacing. They build on this background by choosing six electives from the breadth of the course offerings in the School of Computing and the Department of Electrical and Computer Engineering. The latter include advanced courses in communications, controls, digital signal processing, computer architecture, software systems, integrated circuit design, microwaves, optics, robotics, intelligent systems, and semiconductor devices. Each student's undergraduate program is capped with a senior project or a senior thesis. Along with an in-depth study of computer engineering, the undergraduate curriculum encompasses a general education in mathematics (including discrete math, probability, and statistics), science, and the humanities.

Academic counseling for the Computer Engineering program is currently being handled by the School of Computing.

The University of Utah is committed to policies of equal opportunity, affirmative action, and nondiscrimination. The University seeks to provide equal access to its programs, services, and activities for people with disabilities. Reasonable prior notice is needed to arrange accommodations.

(This handbook is available online at <http://www.cs.utah.edu/dept/handbooks>.)

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The Computer Engineering Major

Computer Engineering includes the design, implementation, and programming of digital computers and computer-controlled electronic systems. The School of Computing and the Department of Electrical and Computer Engineering jointly offer a Bachelor of Science degree in Computer Engineering. The program is administered by the Computer Engineering Committee, which consists of faculty members from both departments.

Computer Engineering is a hardware-oriented degree whose requirements include courses offered by the School of Computing and/or the Department of Electrical and Computer Engineering. A student must be admitted as a major in the program in order to take advanced courses (computer science courses numbered 3000 or higher and electrical engineering courses numbered 2000 or higher) and pursue the Computer Engineering degree.

1.1 Goals of the Computer Engineering Program

The Computer Engineering program is designed with the following objectives:

- To give students, through an undergraduate education grounded in the principles and applications of computer and engineering science, the ability to solve computer engineering problems.
- To prepare students for competent, responsible, and rewarding careers in the computer engineering profession.
- To prepare students who choose to continue on to graduate school for admission and successful completion of a graduate degree.

The Computer Engineering curriculum provides students with a sufficient background in mathematics, computer science, and engineering sciences to analyze and design complex software and hardware systems. The curriculum is designed to ensure that graduates consistently meet the above objectives and that they demonstrate the following program outcomes:

- an ability to apply knowledge of mathematics, science, and engineering
- an ability to design and conduct experiments, to analyze and interpret data, and to debug and analyze software

- an ability to design a system, component, process, or software package to meet desired needs
- an ability to function on multi-disciplinary teams
- an ability to identify, formulate, and solve computer engineering problems
- an understanding of professional and ethical responsibility
- an ability to communicate effectively in both written and oral form
- the broad education necessary to understand the impact of engineering solutions in a global and societal context
- a recognition of the need for, and an ability to engage in, life-long learning
- a knowledge of contemporary issues
- an ability to use the techniques, skills, and modern engineering tools necessary for modern computer engineering practice

1.2 Becoming a Computer Engineering Major

Any student may become a Computer Engineering pre-major by informing the University Registrar or the Computer Engineering Academic Counselor. It is advisable to do this early to ensure receiving program information and staying advised of any changes that may be made in degree requirements. Declaration of a major will also enable participation in activities associated with the degree program such as the Undergraduate Student Advisory Committee.

In order to become a full major, a student must complete the courses required of pre-majors and apply for full major status. An application should be filled out at the School of Computing office any time during the first session of the semester during which he or she expects to complete these requirements. A student may not preregister for any advanced classes in computer engineering without first being admitted to full major status. Applications for admission are reviewed at the end of each semester. The Computer Engineering Committee determines how many new majors will be admitted each year, based upon laboratory facilities, computer resources, and available faculty.

To be considered for admission to full major status, a student must have:

1. An average grade of at least 3.0 and a minimum grade of C– in all of the following classes or their equivalents. *None of these classes may be taken on a credit/no-credit basis.*
 - Mathematics 1210/1220 or 1210/1250.
 - Physics 2210.
 - Computer Science 2010/2020.
 - Electrical Engineering 1000/1020.
 - University English writing requirement
2. A grade of CR in CS 1010 (a credit/no-credit class).
3. A cumulative grade point average of 2.3 or higher. (Note that *much* higher grades in the required classes listed above are required. See below for details.)

Applicants for the CE major are ranked according to their composite grade point averages in the required classes listed above, and the students with the best composite scores are admitted. No student will be admitted whose score is below 3.0. Keep this in mind when estimating your chances for admission.

No pre-major class may be taken more than twice. If a class is repeated, the grade received the second time is used. If a student receives *any* grade in a class—including W (withdrawal), I (incomplete), or V (audit)—the student is considered to

have taken the class. *Only three classes may be repeated without penalty. For any additional classes that a student repeats, only 80% of the grade points received in the repeated class will be used in the GPA calculation.*

If credit is granted for any of the above classes based on advanced placement test scores or courses taken at other schools, grades may be assigned for use in the calculation. Check with the Computer Engineering Academic Counselor for details.

1.3 Undergraduate Advising

Each student in the Computer Engineering major is assigned a faculty advisor. The program also has an Academic Counselor (Sandy Hiskey, 3190 MEB, 581-8224, shiskey@cs.utah.edu) who is available to answer questions regarding registration for CE classes, transfer of credits, degree requirements, recent program actions, etc. The Academic Counselor can also arrange appointments with the faculty advisor.

A student is welcome to meet with the faculty advisor whenever necessary to discuss schedule plans or current problems. The responsibility for arranging an appointment is left to the student. Students should always feel free to seek advice from the advisor regarding their programs and plans.

1.4 Requirements for the Bachelor of Science Degree

The Computer Engineering degree can be completed in four full-time years of study if the student is capable of completing the two-course calculus, computer science, and electrical engineering sequences, along with physics and English writing, during the freshman year. Only strong training in high school will allow a student to begin at this level. If a student must instead take preparatory classes as a freshman, more than four years may be required for earning a degree. In any event, it is important to take the required pre-major classes early to allow advancement to full major status as soon as possible.

1. **General Education:** The General Education requirements are described in the University of Utah General Catalog. The requirements for Computer Engineering majors are more specific.
 - (a) The University writing requirement is required for computer engineering pre-majors.
 - (b) The quantitative reasoning requirement is satisfied by Math 1210/1220 or 1210/1250, which are required for computer engineering pre-majors.
 - (c) Students must take two intellectual explorations courses in each of fine arts, humanities, and social sciences. (The two-course requirement in physical and life sciences is automatically satisfied by the pre-major requirements.) *These six courses must include an ethics course and two upper division courses.* Courses satisfying the ethics requirement are Phil 2500, 3500, 3510, 3520, 3530, and 3540.

Students must pick up a copy of the General Education Program Approval Form from the Computer Engineering Academic Counselor. This must be completed in order to receive approval for your Gen Ed program.
 - (d) The American Institutions requirement can be satisfied by taking one of Economics 2740, History 1700, Honors 2212, or Political Science 1100.

Incoming engineering students may want to consider the Engineering LEAP (E-LEAP) program organized by the Office of Undergraduate Studies. It is a year-long cohort program set up to allow students to take several classes together during their first year on campus. Two of these classes are seminar courses that satisfy University General Education and Diversity requirements; the second of these classes also satisfies the Computer Engineering ethics requirement. The program also includes sections of Writing, Calculus, and Physics. For more information on E-LEAP, contact the College of Engineering Advisor at 585-7769.

2. **University graduation requirements:** The University graduation requirements for the Bachelor of Science degree are described in the University of Utah General Catalog.

- (a) The communication/writing requirement is satisfied by either Writing 3200 or 3400, one of which is required for computer engineering majors. This course must be taken prior to taking the Computer Engineering Senior Project course.
- (b) The quantitatively intensive course requirement is satisfied by CS/EE 3700 and 3810, which are required for computer engineering majors.
- (c) The diversity requirement can be satisfied by taking a course from the approved list as part of the intellectual explorations requirement.
- (d) Students must complete a minimum of 122 semester hours of course work. At least 40 of the 122 hours must be upper division classes. (Upper division classes are numbered 3000 or above. Credits from two-year colleges will not count toward University upper division hours.) At least 30 of the total credit hours and 20 of the last 30 hours must be taken at the University.

3. **Writing:** Two classes in writing are required:

- (a) Either Writing 2010 or ESL 1060 (for students who speak English as a second language) is required.
- (b) Either Writing 3200 or 3400 is required. Writing 3400 is recommended for most students; Writing 3200 is an option for transfer students.

4. **Mathematics and Science:** A minimum of eight math and science courses must be taken.

- (a) One year of calculus (Mathematics 1210/1220 or 1210/1250) is required.
- (b) One year of physics for scientists and engineers (Physics 2210/2220) is required.
- (c) A course in linear algebra and ordinary differential equations (Mathematics 2250) is required.
- (d) A course in advanced calculus (Mathematics 1260 or 2210) is required.
- (e) Students must take one additional class, chosen from among Biology 1000, Chemistry 1210, Math 3150 (Partial Differential Equations), Math 5600 or Computer Science 3200 (Numerical Analysis), and Physics 3740 (Modern Physics).

5. **Computer Engineering:** A minimum of 23 computer engineering classes must be taken. Figure 1.1 gives an example four-year degree program leading to a Bachelor's Degree in Computer Engineering. Figure 1.2 summarizes the prerequisites for computer engineering courses.

- (a) Required. The following classes must be taken:

CPSC 1010	Introduction to Unix
ECE 1000	Introduction to Electrical Engineering
ECE 1020	EE Problem Solving with Matlab
ECE 2000	Electric Circuits
CPSC 2010/2020	Introduction to Computer Science
CPSC 2100	Discrete Mathematics
ECE 2100	Electronics
CPSC 3500	Software Practice
ECE 3530	Probability & Statistics
CPSC/ECE 3700	Digital Design
CPSC/ECE 3710	Computer Design Laboratory
CPSC/ECE 3720	Interfacing Microprocessors & Microcontrollers
CPSC/ECE 3810	Computer Architecture
CPSC/ECE 3991	Junior Seminar
CPSC 4400	Computer Systems

- (b) Technical electives. Six additional Computer Science or Electrical Engineering classes at the 3000, 4000, or 5000 level, totaling at least 18 semester hours, must be taken. CPSC 3050/51, CPSC 5010/20, CPSC 5050/51, and seminars may not be counted. Only one introductory graphics class and only one independent study class may be counted. Also, labs that are directly associated with classes (e.g., ECE 5211) may not be counted as one of the six required classes.

	<i>Fall</i>		<i>Spring</i>	
<i>Freshman</i>	Math 1210 [†]	(4)	Math 1220 [†]	(4)
	CPSC 2010 [†]	(4)	Physics 2210 [†]	(4)
	CPSC 1010 [†]	(0.5)	CPSC 2020 [†]	(4)
	Writing 2010 [†]	(3)	ECE 1000 [†]	(4)
	Gen Ed	(3)	ECE 1020 [†]	(1)
		<u>(14.5)</u>		<u>(17)</u>
<i>Sophomore</i>	ECE 2000	(4)	ECE 2100	(4)
	Physics 2220	(4)	CPSC/ECE 3700	(4)
	Math 2250	(3)	CPSC 2100	(3)
	CPSC/ECE 3810	(4)	CPSC 3500	(4)
		<u>(15)</u>		<u>(15)</u>
<i>Junior</i>	CPSC/ECE 3710	(3)	CPSC/ECE 3720	(4)
	Writing 3400	(3)	ECE 3530	(3)
	CPSC 4400	(3)	CE technical elective	(3)
	CPSC/ECE 3991	(0.5)	Math/science elective	(3)
	Math 2210	(3)	Gen Ed	(3)
	Gen Ed	(3)		
		<u>(15.5)</u>		<u>(16)</u>
<i>Senior</i>	CPSC/ECE 4710	(3)	CE technical elective	(3)
	CE technical elective	(3)	CE technical elective	(3)
	CE technical elective	(3)	CE technical elective	(3)
	Gen Ed	(3)	Gen Ed	(3)
	Gen Ed	(3)	Gen Ed	(3)
		<u>(15)</u>		<u>(15)</u>

This table gives an eight-semester example program leading to a B.S. in Computer Engineering. It is meant only as a guide, since the scheduling of electives and General Education classes depends upon which ones are selected. This schedule assumes adequate high school preparation in mathematics; it is not advisable to take Physics 2210 without some previous training in calculus. Note that Math 1210, Writing, and Computer Science 2010 must all be taken during the fall semester in order to complete the required pre-major classes during the first year. ([†]Class required of pre-majors.)

Figure 1.1: Example Computer Engineering Degree Program

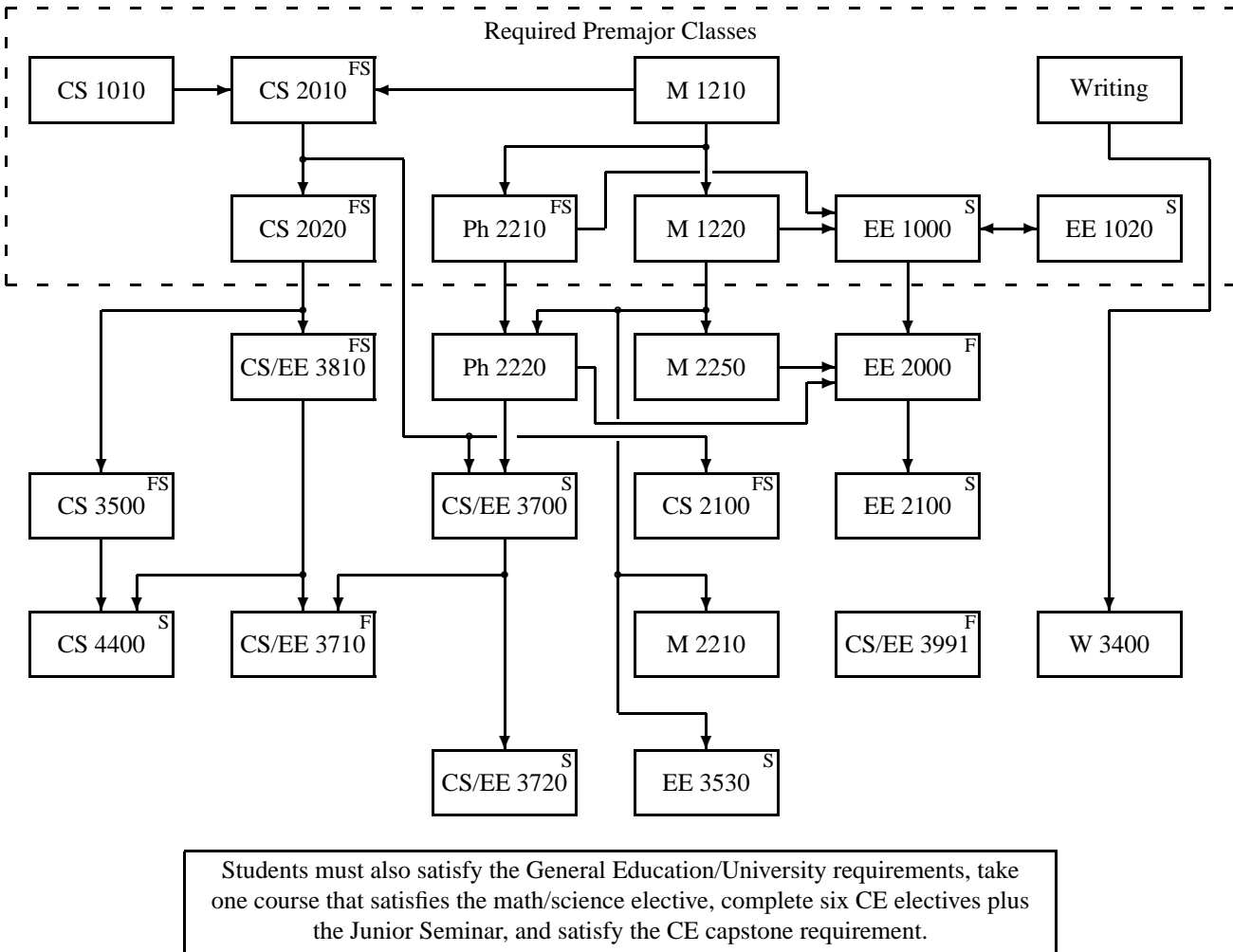
- (c) Capstone Experience. One of the following must be completed.
- CPSC/ECE 4710 Computer Engineering Senior Project
 - CPSC/ECE 3992/4991/4992[†] Pre-thesis and Senior Thesis

[†] *Students choosing the thesis option must get special permission from the CE faculty. Such approval is usually obtained by finding a faculty advisor and completing a thesis proposal in CPSC/ECE 3992 in the Spring of the Junior year. This option is intended for students who are considering graduate school. The Senior Thesis can also be used toward a portion of the thesis requirements for a BS/MS program in Electrical Engineering. For more information about the joint BS/MS program, please see the director of the BS/MS program in the Department of Electrical and Computer Engineering.*

- (d) Duplication of Credit: No single class may be counted toward more than one of the requirements listed above.

6. **Suggested elective grouping.** Some students wish to take technical elective classes that provide a depth of experience in one area of Computer Engineering. Any of the following groups of classes would provide such depth.

- (a) Communications/Controls/Digital Signal Processing
 - ECE 3510 Introduction to Feedback Systems
 - 5000-level or higher courses numbered ECE x5xx or ECE x6xx
- (b) Computer Architecture/Software Systems



This graph shows the order in which classes must be taken to satisfy prerequisite and corequisite requirements in Computer Engineering. Prerequisites are connected bottom-to-top; corequisites are connected side-to-side. Where not otherwise indicated, courses are offered during both semesters as well as the summer.

Figure 1.2: Computer Engineering Prerequisites

CPSC/ECE 5810 Advanced Computer Organization
5000-level or higher courses numbered CPSC x4xx or CPSC/ECE x8xx

(c) Integrated Circuit Design

CPSC/ECE 5710 Advanced Integrated Circuit Design I
5000-level or higher courses numbered CPSC/ECE x7xx

(d) Microwaves/Optics

ECE 3300 Fundamentals of Electromagnetics and Transmission Lines
5000-level or higher courses numbered ECE x3xx or ECE x4xx

(e) Robotics/Intelligent Systems

CPSC 5310 Robotics
5000-level or higher courses numbered CPSC x3xx

(f) Semiconductor Devices (both classes and labs must be taken)

ECE 3110 Electronics II
5000-level or higher courses numbered ECE x1xx or x2xx

7. **Continuing Performance:** *All computer engineering, mathematics, science, and writing courses taken to satisfy the requirements listed above must be passed with a grade of C– or better (except for CPSC 1010, in which a grade of CR is required). A student may repeat such courses only one time. With the exception of the American Institutions requirement and CPSC 1010, all courses listed above must be taken for a letter grade (i.e., they may not be taken CR/NC).*

In order to remain in good standing and to graduate, a student is required to maintain a cumulative grade point average at the University of 2.3 or higher, and also to maintain a grade point average of 2.3 in computer engineering classes. Students whose grade point average in either of these two categories falls below 2.3 are notified that they are on probation and will be given conditions for a return to good standing. Normally, these conditions must be satisfied during the next two semesters, excluding summers. Students failing to meet their probationary conditions are dropped from program rolls.

All students admitted as full majors are placed on probationary status. If a student's GPA in either of the above categories is below 2.3 at the end of the first academic year during which they take upper level CE classes, the student is dropped from the program rolls.

Students are expected to complete all requirements for their degree within four years of acceptance to full major status. Students not making satisfactory progress toward their degrees may be dropped from the program and declared inactive. The determination that a student is not making satisfactory progress is made in one of two ways. Either (1) the student has not completed a CPSC or ECE course for a period of one year, or (2) there is no reasonable way in which the student can complete all degree requirements at the end of the required period of time.

In order to be reinstated from inactive status or from being dropped due to a low GPA, students must petition the Computer Engineering Committee. Reinstated students proceed under the latest graduation requirements.

If personal circumstances prevent completion of all degree requirements within four years of acceptance as a full major in the program, a student may request an extension of a specific duration and submit a revised schedule of completion.

1.5 Undergraduate Financial Assistance

The Computer Engineering Program has several financial assistance awards available. Applications may be picked up from the Computer Engineering Academic Counselor. These scholarships are awarded based upon academic performance, rather than financial need. Most are awarded to CE full majors or those students who will become full majors during the following academic year. Applications for these scholarships must be submitted to the CE Academic Counselor by March 15. The following scholarships are available:

College of Engineering Scholarships. A few awards are available each year to Computer Engineering majors. These are unrestricted cash awards of \$500 to \$2,000. To be eligible, students must take at least 12 credit hours per semester.

Computer Engineering Program Scholarships. These scholarships are awarded on the basis of excellence to students majoring in Computer Engineering. These awards are unrestricted cash awards of \$500 to \$2000, made possible in part by the Whitaker Foundation. To be eligible, students must take at least 9 credit hours per semester. Use the same application as for the College of Engineering Scholarships.

Computer Engineering majors and premajors are also eligible for all scholarships available from the Department of Electrical and Computer Engineering. Applications may be obtained from the department office in MEB 3280 and must be submitted by February 15.

Students may also apply for financial aid from the College of Engineering, which each year awards about 25 Josephine Beam Educational Scholarships. These scholarships are worth approximately \$500 and are based upon need. Obtain an application form from the Office of the Dean of Engineering in Kennecott 214. Applications must be submitted by February 15.

1.6 Employment Opportunities

The University Office of Career Services offers an internship program which allows qualified students to work in their fields of interest for all or part of their junior and/or senior years. This can be done on a full or part time basis, either in Salt Lake City or elsewhere. Students are paid for their work, but no credit is granted. The benefits of such experience include exposure to ideas which could help with career decisions, making contacts which may be useful sometime in the future, and valuable experience in an area that is pertinent to current studies. Among the corporations participating are IBM, Hewlett Packard, Evans & Sutherland, Intel, and Unisys. Many of our majors take advantage of this valuable opportunity.

Both the School of Computing and the Department of Electrical and Computer Engineering employ a number of junior and senior students as computer operators and as teaching assistants. These jobs involve no more than 20 hours of work per week at an appropriate hourly wage. Appointments are made each semester based on student applications, which should be submitted prior to the start of each term. These applications are available in the department offices. In addition, general inquiries are received periodically from local industry and from University of Utah research groups for students who are interested in working part or full time. These are posted on a computer bulletin board which is accessible to majors. More information may be obtained from the Academic Counselor.

Students seeking employment upon graduation should contact the University Office of Career Services in order to be included on a list supplied to employers. Students not planning to work towards an advanced degree should register with Career Services at the beginning of their senior year, since most companies begin interviewing in the fall semester.

1.7 Student Participation in School Affairs

Opportunities for students to develop their organizational and leadership abilities are available through participation in the Computer Engineering Undergraduate Student Advisory Committee (CESAC), which plays an active role in the program and coordinates the following:

1. Course and faculty teaching evaluations.
2. Announcements to all declared pre-majors and majors.
3. Representation on the College Student Advisory Committee.
4. Organization of Engineering Week activities in February.
5. Organization of lunch meetings for pre-majors and majors.
6. Feedback on School issues affecting students, such as scheduling, curriculum changes, and graduation requirements.

1.8 Other Information

More information concerning faculty, facilities, and services in the School of Computing and the Department of Electrical and Computer Engineering can be found in the handbooks for those departments. A listing of courses applicable to the Computer Engineering program is in the next chapter.

2

Computer Engineering Courses

The number and title of each course is followed by the number of semester hours it carries, the semester(s) during which it is taught (F=fall, S=spring, U=summer), its prerequisites, its corequisites, and any courses with which it is cross-listed.

Where a course has both a 5000- and 6000-level number, the 5000-level version is intended for undergraduate and the 6000-level version for graduate students. The two versions of the class will meet together, but extra work will be expected of graduate students.

Current class schedules and registration information¹ are available on line.

ECE 1000 Introduction to Electrical and Computer Engineering (4, S,U) Coreq.: ECE 1020, MATH 1220, PHYCS 2210

The basics of analog and digital circuits as an introduction to electrical and computer engineering. Concepts of voltage, current, power, resistance, and capacitance. Circuit analysis techniques such as Kirchhoff's Laws, branch currents, node voltages, mesh currents, phasors, and impedance. Thevenin's and Norton's equivalent circuits. Design and analysis of simple op amps, RL and RC circuits. Extensive use of Matlab as an analysis and design aid.

CP SC 1010 Introduction to Unix (0.5, FSU)

An introduction to the Unix workstations used in the College of Engineering CADE Lab. Topics include the X Windows system, Unix shell commands, file system issues, text editing with Emacs, accessing the World Wide Web with Netscape, and electronic mail. Self-paced course using online teaching aids.

ECE 1020 EE Problem Solving with Matlab (1, S,U) Coreq.: ECE 1000

Introduction to the Matlab computing language. Arrays, string processing, logical operators, control flow, function files, and plotting. Students design and simulate a simple communications system in Matlab and are introduced to the field of electrical engineering.

ECE 2000 Fundamentals of Electric Circuits (4, F) Prereq.: ECE 1000, 1020; Coreq.: MATH 2250, PHYCS 2220

¹<http://www.acs.utah.edu/student/index.htm>

Laboratory included. Fundamental electric-circuit techniques, including Kirchhoff's laws, superposition, phasor transforms, power in sinusoidal steady-state systems, frequency response, filters, Fourier-series methods, Laplace-transform techniques, and transformers.

CP SC 2010 Introduction to Computer Science I (4, FS) Coreq.: MATH 1210, CP SC 1010

The first course required for students intending to major in computer science and computer engineering. Introduction to the engineering and mathematical skills required to effectively program computers, and to the range of issues confronted by computer scientists. Roles of procedural and data abstraction in decomposing programs into manageable pieces. Introduction to object-oriented programming. Extensive programming exercises that involve the application of elementary software engineering techniques.

CP SC 2020 Introduction to Computer Science II (4, FS) Prereq.: CP SC 2010

The second course required for students intending to major in computer science and computer engineering. Introduction to the problem of engineering computational efficiency into programs. Classical algorithms (including sorting, searching, and graph traversal) and data structures (including stacks, queues, linked lists, trees, hash tables, and graphs). Analysis of program space and time requirements. Extensive programming exercises that require the application of elementary techniques from software engineering.

CP SC 2100 Discrete Structures (3, FS) Prereq.: CP SC 2010

Introduction to propositional logic, predicate logic, formal logical arguments, finite sets, functions, relations, inductive proofs, recurrence relations, graphs, and their applications to Computer Science.

ECE 2100 Fundamentals of Engineering Electronics (4, S) Prereq.: ECE 2000

Laboratory included. Fundamentals of electronic circuits and components, network models of amplifiers, basic semiconductor device physics, diodes, bipolar and MOS transistors, basic analog and digital circuit elements, frequency response, feedback and stability. Introduction to computer circuit simulation.

CP SC 3100 Models of Computation (3, F) Quantitatively Intensive B.S. Course. Prereq.: CP SC 2020, CP SC 2100

Models of sequential computation, including finite-state automata, push-down automata, and Turing machines.

ECE 3110 Engineering Electronics II (4, F) Prereq.: ECE 2100

Laboratory included. Analog and digital integrated circuit techniques, filters and tuned amplifiers, signal generator, waveform shaping circuits, power amplifier and power semiconductor devices, computer models and computer simulations of complex devices and circuits.

CP SC 3200 Scientific Computation (3, S) Prereq.: CP SC 2020, MATH 2250

Scientific computation relevant to computer science and engineering; floating-point arithmetic, systems of linear equations (direct and iterative techniques), nonlinear equations (univariate and multivariate), interpolation and differentiation (divided differences), integration (mechanical and Gaussian quadratures, optimal quadratures), approximation by spline functions (natural splines and B-splines, optimality of splines).

ECE 3300 Fundamentals of Electromagnetics and Transmission Lines (4, F) Prereq.: PHYCS 2220, MATH 2250

Brief introduction to vector calculus, definition of electric and magnetic fields. Maxwell's equations in integral and differential forms, electromagnetic-wave propagation in free space and in material regions, Poynting theorem, and electromagnetic power. Transmission lines (transient and steady-state analysis), Smith chart, and impedance matching techniques. Basic principles of radiation and propagation in waveguides.

CP SC 3500 Software Practice (4, FS) Prereq.: CP SC 2020

Meets with CP SC 5010. Practical exposure to the process of creating large software systems, including requirements specifications, design, implementation, testing, and maintenance. Emphasis on software process, software tools (debuggers, profilers, source code repositories, test harnesses), software engineering techniques (time management, code and documentation standards, source code management, object-oriented analysis and design), and

team development practice. Much of the work will be in groups and will involve modifying preexisting software systems.

ECE 3500 Fundamentals of Signals and Systems (4, F) Prereq.: ECE 2100, MATH 2210

Transform domain analysis of passive circuits. Linear and time invariant systems in continuous-time and discrete-time domains. System representations using impulse response functions, frequency responses and transfer functions. Realizations of linear time-invariant systems. Fourier analysis of continuous and discrete-time signals. Sampling theorem. Filter design from specifications.

CP SC 3510 Advanced Algorithms and Data Structures (4, FS) Quantitatively Intensive B.S. Course. Prereq.: CP SC 2100, CP SC 3500

Meets with CP SC 5020. Study of algorithms, data structures, and complexity analysis beyond the introductory treatment from CP SC 2020. Balanced trees, heaps, hash tables, string matching, graph algorithms, external sorting and searching. Dynamic programming, exhaustive search. Space and time complexity, derivation and solution of recurrence relations, complexity hierarchies, reducibility, NP completeness. Laboratory practice. (Not offered Fall 2002.)

ECE 3510 Introduction to Feedback Systems (4, S) Prereq.: ECE 3500

Laboratory included. Laplace transforms, boundedness, and convergence of signals. Transfer functions, stability, steady-state responses and transient responses, effect of initial conditions, state-space representations. Feedforward and feedback control, steady-state error and integral control, Routh-Hurwitz criterion, root-locus method, application to phase-locked loops. Bode plots, Nyquist criterion, gain and phase margins. The z-transform and the analysis of discrete-time signals and systems. Sampled-data systems, conversion between continuous-time and discrete-time systems.

CP SC 3520 Programming Language Concepts (3, F) Prereq.: CP SC 3500

Ideas behind the design and implementation of programming languages. Syntactic description; scope and lifetime of variables; runtime stack organization; parsing and abstract syntax; semantic issues; type systems; programming paradigms; interpreters and compilers.

ECE 3530 Engineering Probability and Statistics (3, S) Prereq.: MATH 1220

An introduction to probability theory and statistics, with an emphasis on solving problems in electrical and computer engineering. Topics in probability include discrete and continuous random variables, probability distributions, sums and functions of random variables, the law of large numbers, and the central limit theorem. Topics in statistics include sample mean and variance, estimating distributions, correlation, regression, and hypothesis testing. Engineering applications include failure analysis, process control, communication systems, and speech recognition.

CP SC/ECE 3700 Fundamentals of Digital System Design (4, S) Quantitatively Intensive B.S. Course. Prereq.: CP SC 2010, PHYCS 2220

Techniques for minimizing logic functions and designing common combinational circuits such as decoders, selectors, and adders. Synchronous and asynchronous sequential circuits, state diagrams, Mealy and Moore circuits, state minimization and assignment. Use of software tools for design, minimization, simulation, and schematic capture. Implementation with MSI, LSI, and field programmable gate arrays. Laboratory included.

CP SC/ECE 3710 Computer Design Laboratory (3, F) Prereq.: CP SC/ECE 3700, CP SC/ECE 3810

Student groups design, build, and test a programmable device such as a computer or calculator.

CP SC/ECE 3720 Analog & Digital Interfacing with Microprocessors & Microcontrollers (4, S) Prereq.: CP SC/ECE 3700

Fundamentals of digital-to-analog (D-to-A) and analog-to-digital (A-to-D) circuits, relays, stepper motors, and digital switches. Interfacing digital and analog circuits to computers and micro-controllers. Laboratory included.

CP SC/ECE 3810 Computer Architecture (4, FS) Quantitatively Intensive B.S. Course. Prereq.: CP SC 2020

An in-depth study of computer architecture and design, from digital logic to operating systems, including topics such as pipelining, memory systems, parallel and serial communication, and interrupts. Performance measures and compilation issues. Computer architectures including RISC, CISC, stack, and parallel.

CP SC/ECE 3991 Computer Engineering Junior Seminar (0.5, F) Prereq.: CE major status

Presentation from faculty and industry representatives to discuss trends in computer engineering, professionalism, ethics, the impact of engineering in global and societal contexts, lifelong learning, and contemporary issues.

CP SC/ECE 3992 CE Prethesis (0.5, S) Prereq.: CP SC/ECE 3991, CE major status

Students do necessary library research, develop writing and speaking skills, and prepare and present a senior thesis proposal.

CP SC 4010 Teaching Introductory Computer Science (1, FS) Prereq.: Permission of instructor

Issues confronted by undergraduate teaching assistants in introductory computer science courses, including leading lab sections, conducting office hours, grading assignments, communicating with students. Each student must currently be an undergraduate teaching assistant in the School of Computing. May be taken for credit up to three times.

CP SC 4400 Computer Systems (3, FS) Prereq.: CP SC 3500, CP SC 3810; CP SC 3510 recommended

Introduction to computer systems from a programmer's point of view. Machine level representations of programs, optimizing program performance, memory hierarchy, linking, exceptional control flow, measuring program performance, virtual memory, concurrent programming with threads, network programming. *Not offered Fall 2003.*

CP SC 4500 Software Engineering Laboratory (3, S) Prereq.: CP SC 3510, senior standing in Computer Science

Development of significant software systems by small student groups, with emphasis on applying sound, disciplined software engineering practice.

CP SC 4540 Web Software Architecture (3, S) Prereq.: CP SC 3510

Software architectures, programming models, and programming environments pertinent to developing web applications. Topics include client-server model, multi-tier software architecture, client-side scripting (JavaScript), server-side programming (Servlets and JavaServer Pages), component reuse (JavaBeans), database connectivity (JDBC), and web servers.

CP SC 4550 Simulation (3, F) Prereq.: CP SC 3510

Basic simulation modeling, modeling complex systems, basic probability and statistics for simulation, building valid simulations, random numbers, and output data analysis. Both discrete event and continuous simulation may be covered.

CP SC/ECE 4710 Computer Engineering Senior Project (3, F) Prereq.: CP SC/ECE 3710, CP SC/ECE 3720, senior standing in Computer Engineering

Students design a microcomputer system that includes RAM, EPROM, and I/O devices. Capstone project for computer engineering majors. Formal written reports, one or more oral presentations.

CP SC 4950 Independent Study (1–4)**CP SC 4960–4964 Special Topics** (1–4)**CP SC/ECE 4991 CE Senior Thesis I** (2, F) Cross-listed with ECE 4992. Prereq.: CP SC/ECE 3992 and approved senior thesis proposal

Students work on original senior thesis project.

CP SC/ECE 4992 CE Senior Thesis II (2, S) Prereq.: CP SC/ECE 4991

Students work on original senior thesis project, make an oral presentation at the annual student technical conference, and prepare and submit their senior thesis for approval.

CP SC 5100 Foundations of Computer Science (3, S) Prereq.: CP SC 3100, CP SC 3510

Meets with CP SC 6100. Finite Automata and related topics (BDDs, Presburger Arithmetic, and decidable fragments of first-order logic). Automata on Infinite Words, connections with Specification and Verification of Systems. Push Down Automata, Turing Machines, Proofs by Reduction, Diagonalization, Problems in Computability. First-order Logic and Decidability. NP Completeness, P-space Completeness.

ECE 5201 Semiconductor Device Physics I (3, F) Prereq.: MSE 3210 or PHYCS 3740

Physical principles that underlie operation of semiconductor electronic devices with emphasis on silicon integrated circuits. Physics of semiconductor materials, equilibrium in electronic systems, metal semiconductor contacts, p-n junction theory, junction field effect transistors, introduction to operation of bipolar transistors.

ECE 5202 Semiconductor Device Physics II (3, S) Prereq.: ECE 5201

Continuation of ECE 5201. Bipolar transistors, silicon-silicon dioxide system, insulated gate field effect transistors (IGFETs). Mathematical models for computer simulation of bipolar and MOS devices. Second order effects associated with very small geometry devices, and other devices of current interest.

CP SC 5210 Advanced Scientific Computing I (3, F) Prereq.: CP SC 3200, CP SC 3510, MATH 3160

Meets with CP SC 6210. An introduction to existing classical and modern numerical methods and their algorithmic development and efficient implementation. Topics include: numerical linear algebra, interpolation, approximation methods and parallel computation methods for nonlinear equations, ordinary differential equations, and partial differential equations.

ECE 5211 Semiconductor Device Physics Laboratory I (1, F) Coreq.: ECE 5201

Hands on experience in the fabrication of silicon devices. Use of oxidation, donor and acceptor diffusion, and high resolution photolithography in a clean room facility. Characterization of silicon, measurement of basic parameters, oxide thickness, dopant diffusion. Introduction to metalization and contacts.

ECE 5212 Semiconductor Device Physics Laboratory II (1, S) Coreq.: ECE 5202

Integrated knowledge of individual processing steps with more complex processing equipment. Fabricate and characterize simple transistors and integrated circuits.

ECE 5221 Fundamentals of Micromachining Processes (2, F) Prereq.: Instructor's consent

Meets with ECE 6221. Introduction to the principles of micromachining technologies. Topics include photolithography, silicon etching, micro molding, micro electroforming, thin film sacrificial layer technologies, and substrate bonding technologies. Laboratory included.

ECE 5222 Biomedical Applications of Micromachining (2, S) Prereq.: ECE 5221/6221

Meets with ECE 6222. Use of the technologies from the first course in the series (BIOEN 6421) to investigate biomedical applications of micromachining. Course focuses on the design and development of micro sensor/actuator systems; laboratory focus is on the fabrication and testing of microscale sensor/actuator systems. Laboratory included.

CP SC 5300 Artificial Intelligence (3, S) Prereq.: CP SC 3510

Meets with CP SC 6300. Introduction to field of artificial intelligence, including heuristic programming, problem-solving, search, theorem proving, question answering, machine learning, pattern recognition, game playing, robotics, computer vision.

CP SC 5310 Robotics (3, F) Cross-listed with ME EN 5220. Prereq.: CP SC 1000, MATH 2250, PHYCS 2220

Meets with CP SC 6310. The mechanics of robots, comprising kinematics, dynamics, and trajectories. Planar, spherical, and spatial transformations and displacements. Representing orientation: Euler angles, angle-axis, and quaternions. Velocity and acceleration: the Jacobian and screw theory. Inverse kinematics: solvability and singularities. Trajectory planning: joint interpolation and Cartesian trajectories. Statics of serial chain mechanisms. Inertial parameters, Newton-Euler equations, D'Alembert's principle. Recursive forward and inverse dynamics.

CP SC 5320 Computer Vision (3, S) Prereq.: CP SC 3510, MATH 2210, MATH 2270

Meets with CP SC 6320. Basic pattern-recognition and image-analysis techniques, low-level representation, intrinsic images, "shape from" methods, segmentation, texture and motion analysis, and representation of 2-D and 3-D shape. (Not offered 2002–03.)

ECE 5320 Microwave Engineering I (4, F) Prereq.: ECE 3300

General theory of waveguides and transmission lines; TE, TM, TEM modes; some commonly used waveguides and transmission lines including microstripline and its variations for microwave integrated circuits; matching techniques including conjugate matching; passive components, scattering matrices and signal flow graphs; directional couplers and hybrids; power dividers and combiners; signal flow graphs for microwave amplifiers; microwave resonators and filters including design considerations; Ferrite components. Course includes bi-weekly laboratory assignments to design, fabricate and test microstrip circuits using professional level computer software and network analyzers. Demonstrations of waveguide components is also planned.

ECE 5321 Microwave Engineering II (3, S) Prereq.: ECE 5320

Nonlinear and active microwave devices including diodes, mixers, transistors, and negative resistance devices; compressed Smith Chart; balanced and double-balanced mixer design; transistor amplifier theory and design for best gain, stability, and noise performance. Oscillator theory and design using transistors, tunnel diodes, IMPATTs, and Gunn diodes. PIN diode switching circuits and phase shifters. Survey of design and performance of microwave systems and auxiliary components; antennas, signal modulation and multiplexing, transceiver and radar systems, signal-to-noise ratios, atmospheric effects, microwave heating, biological effects and safety. Course includes bi-weekly laboratory assignments using microstrip integrated circuits with professional level design and test equipment. Demonstrations of other active components such as traveling wave tubes, klystrons, and backward oscillators are also provided.

ECE 5324 Antenna Theory and Design (3, S) Prereq.: ECE 3300

General theory of conduction current antennas; linear antennas including dipoles and monopoles; antenna equivalent impedance; design of AM, FM, TV and shortwave broadcast antennas of one or more elements including ground and mutual impedance effects; matching techniques including lumped, shunt and series elements, transmission lines and conjugate matching; receiving antennas; antennas used for mobile communication systems and their radiation characteristics; antenna arrays and their design; wave propagation including propagation via ionosphere or troposphere; loop antennas and Yagi-Uda arrays; antenna synthesis for specified radiation patterns. UHF and microwave antennas including corner reflector antennas, helical antennas, theory of aperture antennas including rectangular and circular apertures; broadband log-periodic antennas; microstrip antennas and phased arrays including applications for wireless communication systems; slot antennas, turnstile, horn and parabolic radiators; considerations for radar antennas and communication links. Antenna ranges and measurement techniques. Laboratory demonstrations of radiation patterns of portable wireless antennas with and without the model of the head.

ECE 5330 Introduction to Microwave Tubes and Electron Devices (3, S) Prereq.: ECE 3300, 5320, MATH 3150

Introduction to design, operation, and application of microwave and millimeter-wave vacuum tubes; klystrons, traveling-wave tubes, backward-wave oscillators, magnetrons, gyrotrons, free-electron lasers.

CP SC 5340 Natural Language Processing (3, F) Prereq.: CP SC 3510

Meets with CP SC 6340. Computational models and methods for understanding written text. Introduction to syntactic analysis, semantic analysis, discourse analysis, knowledge structures, and memory organization. A variety of approaches are covered, including conceptual dependency theory, connectionist methods, and statistical techniques. Applications include story understanding, fact extraction, and information retrieval.

CP SC 5350 Machine Learning (3, F) Prereq.: CP SC 3510; CP SC 5300/6300 recommended

Meets with CP SC 6350. Techniques for developing computer systems that can acquire new knowledge automatically or adapt their behavior over time. Topics include concept learning, decision trees, evaluation functions, clustering methods, explanation-based learning, language learning, cognitive learning architectures, connectionist methods, reinforcement learning, genetic algorithms, hybrid methods, and discovery.

ECE 5410 Lasers and Their Applications (3, F) Prereq.: ECE 3300

Physics and applications of lasers. All major laser types are studied, including semiconductor, gas, dye and solid-state lasers. Emphasis is placed on the properties of laser light and how they are used in a myriad of applications. Hands-on laboratory experience is included.

ECE 5411 Fiberoptic Systems (3, S) Prereq.: ECE 5410

Systematic study of modern optical-fiber communication systems; Loss-limited systems vs. dispersion-limited systems; Point to point links, broadcast and distribution systems, and optical networks; Wavelength-division multiplexing (WDM); and sub-carrier multiplexing (SCM); optical amplifiers and dispersion compensation; Emphasis is on system design. Includes hands-on laboratory experience.

CP SC 5460 Operating Systems (3, F) Prereq.: CP SC 3510, CP SC/ECE 3810, CP SC 4400

Characteristics, objectives, and issues concerning computer operating systems. Hardware/software interactions, process management, memory management, protection, synchronization, resource allocation, file systems, security, and distributed systems. Extensive systems programming.

CP SC 5470 Compiler Principles and Techniques (3, S) Prereq.: CP SC 3100, CP SC 3510, CP SC/ECE 3810, CP SC 4400

Lexical analysis, top-down and bottom-up parsing, symbol tables, internal forms and intermediate languages, run-time environments, code generation, code optimization, semantic specifications, error detection and recovery. Use of software tools for lexical analysis and parsing.

ECE 5470 Ultrasound (2, F) Prereq.: PHYCS 2220

Acoustic-wave propagation in biological materials with examples of practical medical instrumentation resulting from ultrasound interactions with biological structures. Includes one lab experience.

CP SC 5480 Data Communications and Networks (3, F) Prereq.: CP SC 3510, CP SC/ECE 3810, CP SC 4400

Meets with CP SC 6480. A comprehensive study of the principles and practices of data communication and networks. Topics include: transmission media, data encoding, local and wide area networking architectures, inter-network and transport protocols (e.g., IPv4, IPv6, TCP, UDP, RPC, SMTP), networking infrastructure (e.g., routers, name servers, gateways), network management, distributed applications, network security, and electronic commerce. Principles are put into practice via a number of programming projects.

ECE 5510 Random Processes (3, F) Prereq.: ECE 3510, MATH 5010

Review of probability theory; multivariate distributions; Gaussian distributions; weak and strong law of large numbers; random processes; stationarity and ergodicity; mean-value function; auto- and cross-correlation functions; power spectral densities; Wiener-Khinchine theorem; Karhunen-Loeve expansion; Gaussian random processes; random processes in linear filters; white Gaussian noise.

CP SC 5520 Anatomy of a Modern Programming Language (3, S) Prereq.: CP SC 3520

Requirements, challenges, and techniques for designing a modern programming language, currently focusing on Java as a case study. Syntactic and lexical issues, semantic specification, modularity concepts, support for object-oriented programming, types and subtypes, type safety and security, portability, compilability, dynamic linking and loading, program evolvability, use of meta data (reflection), multi-threading, native code generation and linkage, generic types, persistence.

ECE 5520 Digital Communication Systems (3, S) Prereq.: ECE 5510

Modern communications; probabilistic viewpoint; vector representation of signal; signal spaces; vector channels; additive white Gaussian noise; optimum receivers; maximum-likelihood detection; error probabilities; memory-less modulation methods: PAM, BPSK, M-PSK, FSK, QAM; message sequences; intersymbol interference (ISI); Nyquist signaling; complex baseband models; noncoherent detection.

CP SC 5530 Database Systems (3, F) Prereq.: CP SC 3500

Meets with CP SC 6530. Representing information about real world enterprises using important data models including the entity-relationship, relational and object-oriented approaches. Database design criteria, including normalization and integrity constraints. Implementation techniques using commercial database management system software. Selected advanced Topics such as distributed, temporal, active, and multi-media databases.

ECE 5530 Digital Signal Processing (3, F) Prereq.: ECE 3510

Meets with ECE 6530. Discrete-time signals and systems; the z-transform. Input-output relationships; discrete-time networks. The discrete-time Fourier transform and sampling; practical sampling issues; signal quantization. The discrete Fourier transform, the fast Fourier transform, and high-speed convolution. Filter design from analog models; impulse-invariant, bilinear, and spectral transformations. FIR filter design, windowing, and frequency-sampling methods. Equiripple filter design. Coefficient quantization. Examples of DSP applications and implementations.

CP SC 5540 Human/Computer Interaction (3, F) Prereq.: CP SC 3510

Meets with CP SC 6540. Fundamentals of input/output devices, user interfaces, and human factors in the context of designing interactive applications.

ECE 5550 Survey of Function Approximation Methods (3, S) Prereq.: MATH 2210, 2250, 3150

Meets with ECE 6552. Industrial problems requiring function approximations, Fourier series, universal series approximations, fuzzy logic, radial basis functions, neural networks, linear interpolation, triangulation, window reticulation, response surfaces, polynomials, cubic splines, sinc functions, Bezier curves. Offered alternate years.

ECE 5551 Survey of Optimization Techniques (3, S) Prereq.: MATH 2210, 2250, 3150

Meets with ECE 6551. Neural networks, gradient and Hessian descent, conjugate gradient, random search, simulated annealing, prejudicial search, least-squares, regression, downhill simplex, genetic algorithms, linear programming, simplex algorithm, Karmarkar algorithm, quadratic and dynamic programming, Riccati equation, Beard-Galerkin optimal control. Offered alternate years.

ECE 5570 Control of Electric Motors (3, S) Prereq.: ECE 3510

Principles of operation, mathematical models, and control techniques for electric motors. Types of motors include brush DC motors, stepper motors, brushless DC motors, synchronous motors and induction motors. Topics covered: steady-state and dynamic characteristics, torque limits and field weakening operation, characteristics under voltage and current sources, open-loop and closed-loop control of position and velocity, and field-oriented operation for AC motors.

ECE 5580 Implementations of Digital Signal Processing Systems (3, F) Prereq.: ECE 5540, CP SC/ECE 5710

Meets with ECE 6580. Review of common DSP systems and functional elements; number representations. Implementation of bit-parallel, bit-serial, and digit-serial multiplier and adder structures; carry-save arithmetic; register minimization. Architectural transformation techniques: folding and unfolding, pipelining, and retiming of computations. Performance and hardware tradeoffs in VLSI DSP system design. Pipelined and parallel direct-form FIR and IIR filter structures. Pipelined adaptive filter structures. Architectures for the fast Fourier transform.

CP SC 5600 Introduction to Computer Graphics (3, S) Prereq.: CP SC 3500, MATH 2250; Coreq.: CP SC 3510 recommended

Basic display techniques, display devices, and graphics systems. Homogeneous coordinates, transformations, and clipping. Introduction to lighting models. Introduction to raster graphics and hidden-surface removal.

CP SC 5610 Advanced Computer Graphics I (3, F) Prereq.: CP SC 5600

Meets with CP SC 6610. Interactive 3D computer graphics, polygonal representations of 3-D objects. Interactive lighting models. Introduction to interactive texture mapping, shadow generation, image-based techniques such as stencils, hidden-line removal, and silhouette edges. Introduction to image-based rendering, global illumination, and volume rendering.

CP SC 5630 Scientific Visualization (3, F) Prereq.: CP SC 3510; CP SC 3200 or CP SC 5210 or MATH 5600

Meets with CP SC 6630. Introduction to the techniques and tools needed for the visual display of data. Students will explore many aspects of visualization, using a "from concepts to results" format. The course begins with an overview of the important issues involved in visualization, continues through an overview of graphics tools relating to visualization, and ends with instruction in the utilization and customization of a variety of scientific visualization software packages.

CP SC/ECE 5710 Advanced Integrated Circuit Design I (3, F) Prereq.: CP SC/ECE 3700

Meets with CE 6710. Introduction to basic concepts of the design of CMOS integrated circuits for students with a wide range of backgrounds. Static and dynamic properties of CMOS circuits, composite layout of CMOS circuits, and modeling of transistors for use in SPICE simulations. Commonly encountered CMOS circuits. Introduction to CMOS analog/digital circuits. Students complete design, composite layout, and digitization of a simple integrated circuit using computer-aided design tools.

CP SC/ECE 5720 Advanced Integrated Circuit Design II (3) Prereq.: CP SC/ECE 5710/6710, ECE 2100

Meets with CE 6720. Design of mixed signal (analog/digital) CMOS integrated circuits. Fundamental building blocks for analog circuits, including the basic principles of opamp, current mirror and comparator design. Basics of discrete-time signals and filters. Implementation of switched capacitor circuits and discussions of various implementations of D/A and A/D converters, oversampled converters and phase locked loops. (Not offered 2002–03.)

CP SC/ECE 5740 Computer-Aided Design of Digital Circuits (3) Prereq.: CP SC/ECE 3700, CP SC 3510

Meets with CE 6740. Introduction to theory and algorithms used for computer-aided synthesis of digital integrated circuits. Topics include algorithms and representations for Boolean optimization, hardware modeling, combination logic optimization, sequential logic optimization and technology mapping. (Not offered 2002–03.)

CP SC/ECE 5750 Synthesis and Verification of Asynchronous VLSI Systems (3, F) Prereq.: CP SC/ECE 3700, CP SC 3510

Meets with CE 6750. Introduction to systematic methods for the design of asynchronous VLSI systems from high-level specifications to efficient, reliable circuit implementations. Topics include specification, controller synthesis, optimization using timing information, technology mapping, data path design, and verification. (Not offered 2002–03.)

CP SC/ECE 5810 Advanced Computer Architecture (3, F) Prereq.: CP SC/ECE 3700, CP SC/ECE 3810

Meets with CE 6810. Principles of modern high performance computer and micro architecture: static vs. dynamic issues, pipelining, control and data hazards, branch prediction and correlation, cache structure and policies, cost-performance and physical complexity analyses.

CP SC/ECE 5830 VLSI Architecture (3) Prereq.: CP SC/ECE 3700, CP SC/ECE 3810

Meets with CE 6830. Project-based study of a variety of Topics related to VLSI systems. Use of field programmable gate arrays to design, implement, and test a VLSI project. (Not offered 2002-03.)

CP SC 5950 Independent Study (1–4)**ECE 5950 Undergrad Special Study** (1-12, FSU)

CP SC 5960–5969 Special Topics (1–4)

The following special topics courses are currently scheduled for the 2003–04 academic year. Contact the faculty member in charge for details. Check the on-line schedule for a more current listing of offerings.

- **CP SC 5960 Computational Geometry** (3,F). Prof. Praun.
- **CP SC 5961 Parallel Programming** (3,S). Prof. Berzins.
- **CP SC 5962 Games Graphics** (3,S). Prof. Hansen.
- **CP SC 5963 Advanced Manufacturing** (3, F). Prof. Drake.

ECE 5960–5961 Special Topics (1-5, FSU)**CP SC 6110 Formal Methods for System Design** (3, S) Prereq.: CP SC 5100/6100 and CP SC 6520

Study of methods for formally specifying and verifying computing systems. Specific techniques include explicit state enumeration, implicit state enumeration, automated decision procedures for first-order logic, and automated theorem proving. Examples selected from the areas of superscalar CPU design, parallel processor memory models, and synchronization and coordination protocols. (Not offered 2002–03.)

CP SC 6220 Advanced Scientific Computing II (3, S) Prereq.: CP SC 5210/6210 or MATH 5600

A study of the numerical solution of two and three dimensional partial differential equations that arise in science and engineering problems. Topics include: finite difference methods, finite element methods, boundary element methods, multigrid methods, mesh generation, storage optimization methods, and adaptive methods.

ECE 6261 Physical Theory of Semiconductor Devices (3, F) Prereq.: ECE 5202

Development of a thorough, working knowledge of the physics of semiconductor materials and devices, including quantum effects. Examination of advanced devices, including light emitting diodes, solar cells, detectors, and injection lasers. Offered alternate years.

ECE 6262 Advanced Optoelectronics (3, S) Prereq.: ECE 5411

Introduce the technology of ultrafast diode lasers from the basic physical principles through to the applications in communications and ultrafast optoelectronic and applications of semiconductor diode laser arrays. All of the major types of arrays will be discussed including coherent, incoherent, edge- and surface-emitting, horizontal- and vertical-cavity, individually addressed, lattice-matched and strained-layer systems. Offered alternate years.

ECE 6263 Advanced Classical and Quantum Semiconductor (2, S) Prereq.: ECE 6261 or 5202

This class will be a lecture/laboratory course focusing on advanced principles of operation, physical design considerations, and testing of advanced Si, SiGe, SiC, and III-V compound semiconductor devices. Ohmic and Schottky contact technologies will be discussed in detail. Advanced applications of MESFETs and JFETs will also be presented. The primary thrust of this course will be on HEMTs, HBTs, MBTs, graded junction/alloy transistors, resonant tunneling transistors and other quantum and superlattice devices. Trade-offs, theoretical considerations, modeling and simulation, testing, and the correlation between theory and experiment for various device parameters will be covered. Offered alternate years.

ECE 6264 Advanced Silicon Devices (3, S) Prereq.: ECE 6261 or 5202

Current topics in silicon device physics. Review of MOS device theory, rules for scaling devices to submission dimensions, theoretical limits to scaling. Short channel, device models including two-dimensional numerical models. Hot carrier effects and other reliability issues. Yield statistics, lifetime prediction.

ECE 6265 Advanced Processing of Semiconductors (3, S) Prereq.: ECE 6261 or 5202

Development of a thorough, working knowledge of the thermodynamic and kinetic aspects of epitaxy. This material is used to illustrate the advanced epitaxial techniques of organometallic vapor phase epitaxy, chemical beam epitaxy, and molecular beam epitaxy. Offered alternate years.

ECE 6266 Advanced Semiconductor Device Characterization (2, S) Prereq.: ECE 6261 or 5202

This class will be a lecture/laboratory course focusing on advanced characterization, measurement, and testing of semiconductor devices. Topics include: MIS/MOS interface and bulk trap measurement and analysis using HF/Ideal, LF/HF, LF/Ideal, Multifrequency (Conductance) capacitance versus voltage (C-V) curves, BTS and TVS testing of oxides, Fowler Nordheim and Poole Frenkel currents in oxides and insulators, Charge Pumping, two-, three-, and four-terminal MOS current vs. Voltage (I-V) measurements, measuring hot Electron/Short Channel Effects, C-t/Zerbst Plots, Silicide technology, Electronmigration effects, DLTS, I-V versus temperature of MOS and BJTs. Offered alternate years.

ECE 6310 Advanced Electromagnetic Fields (3, F) Prereq.: ECE 3300

Review of Maxwell's macroscopic equations in integral and differential forms including boundary conditions, power and energy computations, and time-harmonic formulations. Macroscopic electrical properties of matter. Oblique incidence planewave propagation and polarization in multi-layered media. Separation of variable solutions of the wave equation in rectangular, cylindrical and spherical coordinates. Vector potential theory and the construction of solutions using Green's theorem. Electromagnetic theorems of duality, uniqueness, reciprocity, reaction, and source equivalence. Waveguide, cavity, antenna, and scattering applications in rectangular, cylindrical, and spherical geometries.

ECE 6320 Advanced Microwave Integrated Circuits (3, S) Prereq.: ECE 5321

This class deals with design and technology of microwave integrated circuits (MICs) and Monolithic Microwave Integrated Circuits (MMICs). Microwave integrated circuits such as small-signal amplifiers, power amplifiers, and oscillators are studied. Nonlinear circuits such as frequency multipliers and mixers are also covered in detail. Active devices are studied for microwave circuit and system applications. Transistors, both bipolars and FETs, and various two terminal devices are also discussed. This class deals with fabrication techniques and measurements related to microwave integrated circuits. Testing, packaging and reliability issues are studied. This class also covers monolithic microwave integrated circuit techniques. This class involves extensive computer-aided designs, circuit layout and fabrication, and circuit characterization and testing of MICs and MMICs. Offered alternate years.

ECE 6330 Microwave Devices and Physical Electronics (3, F) Prereq.: ECE 5321

State-of-the-art course in microwave thermionic devices: Formation and control of electron beams. Llewellyn Peterson equations, space-charge waves, klystrons, traveling-wave tubes. Offered alternate years.

ECE 6331 Microwave Devices and Physical Electronics (3, S) Prereq.: ECE 6330

State-of-the-art course in microwave thermionic devices: Continuation of traveling-wave tubes, backward-wave oscillators, crossed-field devices, parametric amplifiers, gyrotron devices, and free-electron lasers. Offered alternate years.

ECE 6340 Numerical Techniques in Electromagnetics (3, S) Prereq.: ECE 3300, MATH 2210, 2250

Review of basic numerical techniques including matrix methods and numerical methods for error minimization and convergence. Comparison of differential and integral formulations including finite difference, finite element, and moment methods. Emphasis on frequency domain method of moments and time domain finite difference (FDTD). Computer exercises require FORTRAN, C, or equivalent programming and computerized data display techniques. Offered alternate years.

CP SC 6360 Virtual Reality (3, S) Prereq.: CP SC 5310/6310

Human interfaces: visual, auditory, haptic, and locomotory displays; position tracking and mapping. Computer hardware and software for the generation of virtual environments. Networking and communications. Telerobotics: remote manipulators and vehicles, low-level control, supervisory control, and real-time architectures. Applications: manufacturing, medicine, hazardous environments, and training. (Not offered 2002-03.)

ECE 6420 Fourier Optics and Holography (3, F) Prereq.: ECE 3300, 5410

Analysis of optical systems by use of spatial Fourier transforms. A systems approach to optics using spatial frequencies and transfer functions to analyze diffraction, filtering, and imaging. Holography and holographic optical

elements used in optical signal processing techniques. Includes two laboratory experiences. Offered alternate years.

ECE 6430 Statistical Optics, Interferometry, and Detection (3, F) Prereq.: ECE 5410, 6420, 5510

Coherence properties of light, including partial temporal and spatial coherence, as measured by statistical functions. Review of basic statistical concepts. Intensity fluctuations of thermal and laser light. Michelson interferometry, Wiener-Khinchin theorem, Young's experiment and the Van Cittert-Zernike theorem. Origins and statistics of optical noise. Comparison of various detection techniques. Includes two laboratory experiences. Offered alternate years.

ECE 6440 Integrated Optics and Optical Sensors (3, S) Prereq.: ECE 5410, 5411

Planar and rectangular waveguides and their mode properties. Fabrication techniques, input and output couplers, and coupling between guides. Integrated optic modulators. Applications of integrated optical devices. Optical sensors for biomedical and environmental monitoring. Includes two laboratory experiences. Offered alternate years.

ECE 6450 Quantum Electronics (3, F) Prereq.: ECE 3300, 5410, PHYS 3740

Advanced quantum mechanical analysis of the interaction of light with matter, including quantization of lattice vibrations and the electromagnetic field. Analysis of laser principles based on quantum mechanical principles. Offered alternate years.

ECE 6451 Nonlinear Optics and Spectroscopy (3, S) Prereq.: ECE 6450

Theoretical development and applications of nonlinear optical processes including harmonic generation, sum and difference frequency generation, parametric oscillation. Nonlinear refractive indices and multiphoton absorption. Offered alternate years.

CP SC 6470 Advanced Topics in Compilation (3, F) Prereq.: CP SC 5470

Compilation of modern languages. Optimization techniques, register allocation and instruction scheduling, garbage collection, exception handling. Linkers and late-stage compilation and optimization. (Not offered 2002–03.)

ECE 6510 Statistical Communication Theory (3, S) Prereq.: ECE 5510, 5520

Efficient modulation; the capacity theorem; Shannon bound; signal constellations, lattices; maximum-likelihood sequence detection; maximum-a-posteriori symbol detection; communication channels; statistical description of channels; multipath fading channels; Optimal detection; diversity detection; spread-spectrum communications; spreading sequences; Gold codes; multiple-access communications; code-division multiple access (CDMA); Aloha and random access communications. Offered alternate years.

CP SC 6520 Programming Languages and Semantics (3, S) Prereq.: CP SC 3520, CP SC 3100

Examination of the formal and pragmatic ideas behind programming language design. Imperative, functional, logic, object-oriented, and multi-paradigm languages. Lambda calculus, fixpoints, type systems, and predicate logic. Denotational semantics and models of concurrency.

ECE 6520 Information Theory and Coding (3, S) Prereq.: ECE 5510, 5520

Concept of Information; uncertainty; entropy; source and channel models; source coding; Huffman codes; Shannon's source coding theorem; channel coding; Shannon's channel coding theorem; bandwidth and the Shannon bound; linear block codes; elements of Galois field theory; cyclic codes; encoding and decoding; classical block codes: BCH, Reed-Solomon (RS) codes; algebraic decoding, efficient decoding of BCH and RS codes. Offered alternate years.

ECE 6521 Error Control Coding (3, S) Prereq.: ECE 5510, 5520

Modern communications systems; additive white Gaussian noise; bandwidth and power constraints; soft-decision decoding; tree codes; tree decoders; the M-algorithm; convolutional codes; trellis codes; decoding methods; maximum a-posteriori symbol detection (MAP), soft information processing; iterative decoding, Turbo coding principles. Offered alternate years.

ECE 6540 Estimation Theory (3, S) Prereq.: ECE 5510, 5540

Bayesian parameter estimation; unbiased estimators; minimum variance estimators. Sufficient statistics; maximum-likelihood estimation; the Cramer-Rao bound. Linear estimation; minimum-mean-square-error estimation and its geometrical interpretation. Wiener filtering; spectral factorization. Kalman filtering and state-space estimation. Applications of estimation to practical problems including system identification and spectrum estimation. Offered alternate years.

ECE 6550 Adaptive Filters (3, S) Prereq.: ECE 5510, 5540

Basics of minimum mean-square and least squares estimation. Lattice orthogonalization. Stochastic gradient adaptive filters: derivations, performance analyses and variations. Recursive least-squares adaptive filters: fast algorithms, least-squares lattice filters, numerical issues, and performance comparisons with stochastic gradient adaptive filters. Adaptive IIR filters. Fundamentals of adaptive nonlinear filtering. Selected applications. Offered alternate years.

ECE 6560 Multivariable Systems (3, F) Prereq.: ECE 3510; ME EN 5210 recommended

State-space models, controllability, observability, model reduction, and stability. Matrix fraction descriptions, coprimeness, properness, state-space realizations, multivariable poles and zeros, and canonical forms. Linear quadratic control, pole placement, and model reference control. Frequency-domain analysis and optimization. Offered alternate years.

ECE 6570 Adaptive Control (3, F) Prereq.: ECE 3510; ME EN 5210 recommended

Identification using gradient and least-squares algorithms. Indirect adaptive control: pole placement control, model reference control, predictive control, and problems with singularity regions. Direct adaptive control: strictly positive real transfer functions, Kalman-Yacubovitch-Popov lemma, passivity theory, and stability of pseudo-gradient adaptive algorithms. Persistency of excitation and sufficient richness conditions for parameter convergence. Averaging methods and robustness issues. Disturbance rejection. Offered alternate years.

CP SC 6620 Advanced Computer Graphics II (3, S) Prereq.: CP SC 5610/6610

Introduction to ray-tracing. Intersection methods for 3-D objects, reflection and refraction. Introduction to surface and solid texturing. Introduction to continuous-tone pictures and the aliasing problem. Special effects such as soft shadows, depth-of-field, motion-blur, and indirect lighting.

ECE 6640 Advanced Digital Signal Processing I (3, F) Prereq.: ECE 5510, 5540

Project-oriented class on advanced topics of current interest in signal processing. Examples of topics include image compression, nonlinear signal processing, active noise control, blind deconvolution and equalization. Offered alternate years.

ECE 6641 Advanced Digital Signal Processing II (3, F) Prereq.: ECE 5510, 5540, 6640

Project-oriented class on advanced topics of current interest in signal processing. Examples of topics include image compression, nonlinear signal processing, active noise control, blind deconvolution and equalization. Offered alternate years

CP SC 6650 Image Synthesis (3, F) Prereq.: CP SC 5620/6620, CP SC 6670, MATH 5010

Using camera and sensor simulation along with physical simulation to generate realistic synthetic images. (Not offered 2002–03.)

CP SC 6670 Computer-Aided Geometric Design I (3, F) Prereq.: MATH 2210, MATH 2250, CP SC 3510; Coreq.: CP SC 5600/6600**CP SC 6680 Computer-Aided Geometric Design II** (3) Prereq.: CP SC 6670

Introduction to current concepts and issues in CAGD systems with emphasis on free- form surface design; mathematics of free-form curve and surface representations, including Coons patches, Bezier method, B-splines, triangular

interpolants, and their geometric consequences; classical surface geometry; local and global design tradeoffs and explicit and parametric tradeoffs; subdivision and refinement as techniques in modeling; current production capabilities compared to advanced research. Laboratory experiments with current CAD systems. (Not offered 2002–03.)

CP SC/ECE 6710 Advanced Integrated Circuit Design I (3, F) Prereq.: CP SC/ECE 3700

Meets with CE 5710. Graduate and honors students only. Extra work required.

CP SC/ECE 6720 Advanced Integrated Circuit Design II (3) Prereq.: CP SC/ECE 5710/6710, ECE 2100

Meets with CE 5720. Graduate and honors students only. Extra work required. (Not offered 2002–03.)

CP SC/ECE 6740 Computer-Aided Design of Digital Circuits (3) Prereq.: CP SC/ECE 3700, CP SC 3510

Meets with CE 5740. Graduate and honors students only. Extra work required. (Not offered 2002–03.)

CP SC/ECE 6750 Synthesis and Verification of Asynchronous VLSI Systems (3, F) Prereq.: CP SC/ECE 3700, CP SC 3510

Meets with CE 5750. Graduate and honors students only. Extra work required. (Not offered 2002–03.)

CP SC/ECE 6770 Advanced Digital VLSI Systems Design (3) Prereq.: CP SC/ECE 5710/6710

Full custom, high speed, high performance CMOS circuit design issues, methodologies, and techniques. Failure modes, modeling techniques, testing, clock skew analysis, clock distribution, power analysis, power line distribution, electrical rules checking, megacell design flow, and other important design issues. (Not offered 2002–03.)

CP SC/ECE 6810 Advanced Computer Architecture (3, F) Prereq.: CP SC/ECE 3700, CP SC/ECE 3810

Meets with CE 5810. Graduate and honors students only. Extra work required.

CP SC/ECE 6820 Parallel Computer Architecture (3) Prereq.: CP SC/ECE 5810/6810

Architecture, design, and analysis of parallel computer systems: vector processing, data vs. control concurrency, shared memory, message passing, communication fabrics, case studies of current high performance parallel systems. (Not offered 2002–03.)

CP SC/ECE 6830 VLSI Architecture (3) Prereq.: CP SC/ECE 3700, CP SC/ECE 3810

Meets with CE 5830. Graduate and honors students only. Extra work required. (Not offered 2002–03.)

CP SC 6950 Independent Study (1–4)

CP SC 6960–6969 Special Topics (1–4)

The following special topics course is currently scheduled for the 2003–2004 academic year. Contact the instructor for details. Check the on-line schedule for a more current listing of offerings.

- **CP SC 6963 Numerical Linear Algebra** (3,S). Prof. Sikorski.

ECE 6960–6961 Special Topics (1-5, FSU)

CP SC 7120 Information-Based Complexity (3) Prereq.: CP SC 3200, MATH 2270, MATH 3210

Analysis of optimal computational methods for continuous problems. Introduction to the general worst case theory of optimal algorithms, linear problems, and spline algorithms as well as selected nonlinear problems. Examples include optimal integration, approximation, nonlinear zero finding, and fixed points. (Not offered 2002–03.)

CP SC 7240 Sinc Methods (3, S) Prereq.: CP SC 5210/6210 or MATH 5600 or MATH 5610

Sinc methods for solving difficult computational problems, such as partial differential and integral equation problems, that arise in science and engineering research. Emphasis on parallel computation. Applications vary, depending on participants in the class. Students are given projects—whenever possible in their areas of research—that lead to publishable research articles. (Not offered 2002–03.)

CP SC 7310 Advanced Robotics (3, S) Cross-listed with ME EN 7230. Prereq.: CP SC/ME EN 5310/6310 5220/6220

Covers the kinematics, dynamics, and control of robotic manipulators. Projects controlling robots will be an integral part of the course.

ECE ONLY 7310 Advanced Topics in Magnetic Resonance Imaging (3, S) Prereq.: Instructor consent

In-depth study of physics and mathematics of MR imaging and MR spectroscopy as they relate to imaging of biologic systems: NMR physics, Bloch's equations, pulse sequences, flow and diffusion phenomena, spectroscopy principles, methodology. Laboratory. Offered alternate years.

ECE ONLY 7320 3-D Reconstruction Techniques in Medical Imaging (3, S) Prereq.: Instructor consent

Physics and mathematics of three-dimensional reconstruction techniques in medical imaging: projection slice theorem, backprojection techniques, analytical and iterative reconstruction algorithms, numerical methods; applications in X-Ray CT, SPECT, PET, and NMR. Laboratory. Offered alternate years.

CP SC 7460 Advanced Operating Systems (3) Prereq.: CP SC 5460, CP SC 5480/6480

Practical distributed operating systems concepts from basics through the state of the art. Topics include interprocess communication, client-server systems, distributed shared memory, distributed file systems, distributed databases, portable computing, software fault tolerance, and wide-area (e.g. web) applications. Work includes individual oral presentations, a group project, and a written research report. (Not offered 2002–03.)

CP SC 7960 Special Topics (1–4)

No special topics courses are currently scheduled for the 2003–2004 academic year. Check the on-line schedule for a current listing of offerings.