Computer Engineering Undergraduate Handbook

University of Utah
Computer Engineering Program
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1998–1999

The Departments of Computer Science and Electrical Engineering jointly offer a Bachelor of Science degree in Computer Engineering. 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 seven core courses in electric circuits, electronics, digital system design, computer architecture, software engineering, computer design, and microprocessor interfacing. They build on this background by choosing two additional core courses (from among operating systems, signals and systems, algorithms and data structures, and electromagnetics and transmission lines) and by choosing five electives from the breadth of the course offerings in Computer Science and Electrical 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. Along with an in-depth study of computer engineering, the undergraduate curriculum encompasses a general education in mathematics, science, and the humanities.

Academic counseling for the Computer Engineering program is currently being handled by the Department of Computer Science.

(This handbook is available online at `http://www.cs.utah.edu/csinfo/handbooks`.)

Computer Engineering Program Administration

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1 The Computer Engineering Major

The Departments of Computer Science and Electrical Engineering jointly offer a Bachelor of Science (B.S.) 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 22 courses offered by Computer Science and/or Electrical 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.

Because of the transition to semesters during the 1998–99 academic year, the requirements for students applying for full major status during the summer of 1998 are slightly different than those for students applying during the summer of 1999 or later. The requirements listed below are as specific as possible in that regard. If special cases arise, consult with the Computer Engineering Academic Counselor.

The requirements in this chapter do not apply to students who were admitted to full major status prior to the summer of 1998. Such students should consult previous years' handbooks and complete an Academic Program Completion Plan.

Throughout this handbook, courses with three-digit numbers are quarter-length courses offered prior to the fall semester of 1998, and courses with four-digit numbers are semester-length courses offered thereafter.

1.1 Becoming a Computer Engineering Major

Any student may become a Computer Engineering pre-major by filling out the appropriate form provided by the Registrar. 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.

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 Department of Computer Science office before the end of the spring semester of the year of application, whether or not the student intends to take additional required classes during the summer. A student may not preregister for any advanced classes in Computer Science or Electrical Engineering without first being admitted to full major status. Applications for admission are reviewed between May and August each year. 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 during the summer of 1998, 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:
   - Mathematics 111/112/113
   - Physics 221/222
   - Computer Science 201/202
   - Electrical Engineering 120/133
   - University English writing requirement
2. A grade of CR in CS 110 (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.)

To be considered for admission to full major status during the summer of 1999 or later, 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:
   - Mathematics 1210/1220 or 111/112/113. (Consult the Mathematics Department for information on satisfying this requirement with a mixture of quarter- and semester-length courses.)
   - Physics 2210/2220 or 221/222/223. (Consult the Physics Department for information on satisfying this requirement with a mixture of quarter- and semester-length courses.)
   - Computer Science 2010/2020 or 201/202/2030. (CS 2030 will be taught only during the fall semester of 1998, and not thereafter. Students who have completed the CS 201/202 sequence under quarters but who plan to apply for full major status during the summer of 1999 or later must take CS 2030 in 1998.)
   - Electrical Engineering 1000/1010 or 120/133.
   - University English writing requirement
2. A grade of CR in CS 1010 or 110 (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.

All classes used in the calculation must be taken for letter grades. *Credit/no-credit grades are not acceptable,* except in CS 110 and CS 1010. Furthermore, each class may be repeated only once. If a class is repeated, only the second grade received is used. If a student registers for a class and later withdraws, resulting in a grade of W, or if a student receives a grade of I or V, that is considered to be one of the two allowable times to register for it. *In addition, only four classes may be repeated without penalty; for the fifth and any subsequent classes that a student repeats, only 80% of the grade points received on the first repeat are used in the evaluation.*

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.

1.2 Undergraduate Advising

Each student in the Computer Engineering major is assigned a faculty advisor. The program also has an Academic Counselor (Mary Rawlinson, 3190 MEB, 581-8224, `mrawlins@cs.utah.edu`) who is available to answer questions regarding registration for 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.

1.3 Requirements for the B.S. 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, physics, computer science, and electrical engineering sequences, along with 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 the normal 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. (If you are classified by the University as a semester transition student, you can elect to satisfy the old Liberal Education requirements instead.)
   (a) The University writing requirement is required for Computer Engineering pre-majors.
   (b) The quantitative reasoning requirement is satisfied by Math 1210/1220 or 111/112/113, 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, a pair of courses that forms an approved concentration, an upper division course, and either an additional concentration or an additional upper division course.

       The second course of a concentration further develops issues introduced in the first. A list of courses satisfying the ethics requirement, a list of sample concentrations, and the General Education Program form are available from the Academic Counselor. Students must complete this form and receive approval for their programs.
   (d) The American Institutions requirement can be satisfied by taking one of Economics 2740 or 274, History 1700 or 170, or Political Science 1100 or 110.

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 Writing 3400 or 301, 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 300/3000 or above. Two-year college credits 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. (For the purposes of this requirement, one semester hour is equivalent to 1.5 quarter hours.)

3. **Mathematics and Science:** A minimum of eight math and science courses must be taken.
   (a) One year of calculus (Mathematics 1210/1220 or 111/112/113) is required. (Consult the Mathematics Department for information on satisfying this requirement with a mixture of quarter- and semester-length courses.)
   (b) One year of physics for scientists and engineers (Physics 2210/2220 or 221/222/223) is required. (Consult the Physics Department for information on satisfying this requirement with a mixture of quarter- and semester-length courses.)

	Fall		*Spring*	
Freshman	Math 1210†	(4)	Math 1220†	(4)
	Physics 2210†	(4)	Physics 2220†	(4)
	CS 2010†	(4)	CS 2020†	(4)
	CS 1010†	(0.5)	EE 1000	(4)
	Writing 2010†	(3)	EE 1010	(0.5)
		(15.5)		(16.5)
Sophomore	EE 2000	(4)	EE 2100	(4)
	Math 2250	(3)	CS/EE 3700	(4)
	CS 3500	(4)	Math/science elective	(3)
	CS/EE 3810	(4)	CE restricted elective	(3)
		(15)		(14)
Junior	CS/EE 3710	(3)	CS/EE 3720	(4)
	CE restricted elective	(3)	Writing 3400	(3)
	Math/science elective	(3)	CE elective	(3)
	Gen Ed	(3)	Math/science elective	(3)
	Gen Ed	(3)	Gen Ed	(3)
		(15)		(16)
Senior	CS/EE 4710	(3)	CE elective	(3)
	CE elective	(3)	CE elective	(3)
	CE elective	(3)	Gen Ed	(3)
	Gen Ed	(3)	Gen Ed	(3)
	Gen Ed	(3)	Free elective	(3)
		(15)		(15)

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 college algebra and trigonometry. Note that Math 1210, Physics 2210, 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. Students whose background is not adequate will need to take one or more of Math 1050 or Math 1060. (†Class required of pre-majors.)

Figure 1.1: Example Computer Engineering Degree Program

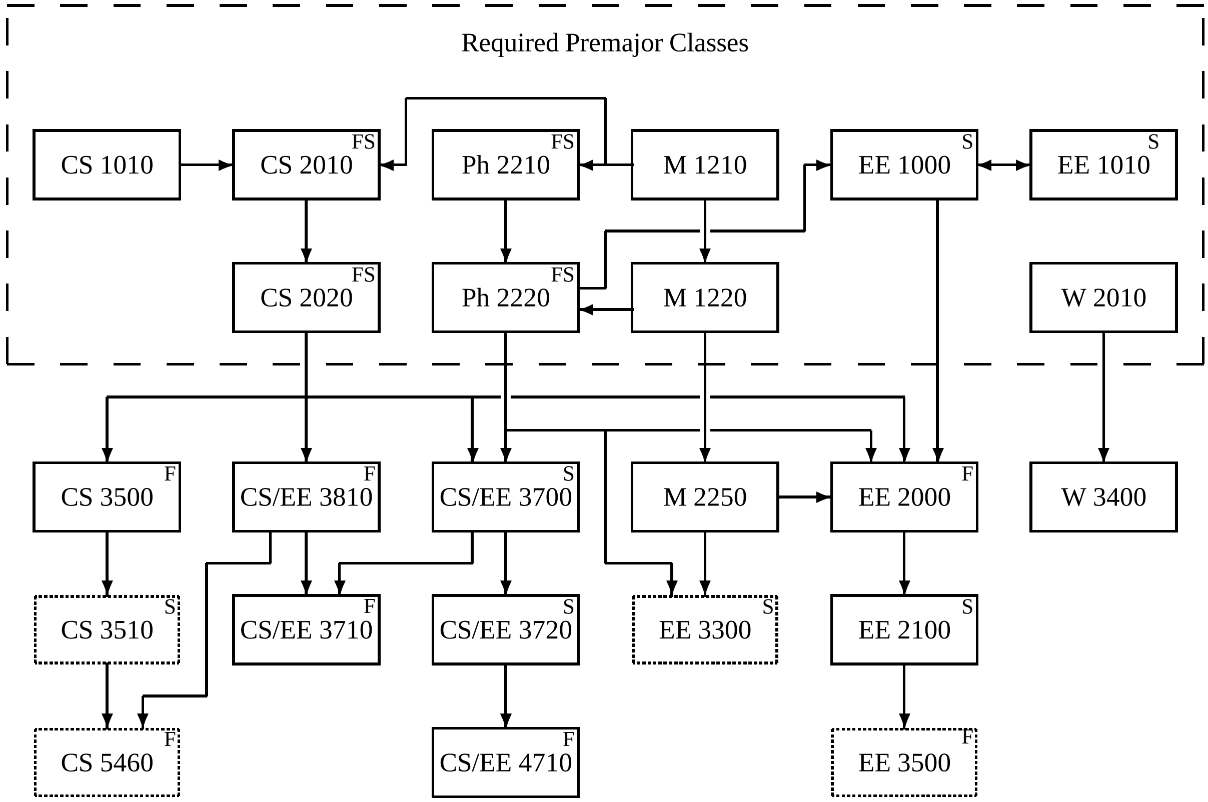
(c) A course in linear algebra and ordinary differential equations (Mathematics 2250 or 251/252) is required.

(d) Students must take three additional classes chosen from among Chemistry 1210 or 121, Biology 1000 or 101, Math 2210 (Calculus III), Math 3150 or 353 (Partial Differential Equations), Math 5010 or 507 (Probability), Math 5600 or 560 (Numerical Analysis), and Physics 3740 or 374 (Modern Physics). At least one of these three classes must be in mathematics and at least one must be in science. Students should take the prerequisites of computer engineering electives into consideration when planning how to satisfy this requirement.

4. **Computer Engineering:** A minimum of 22 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 summarizes the prerequisites for computer engineering courses.

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

CS 1010 or 110	Introduction to Unix
EE 1000 or 120	Introduction to Electrical Engineering
EE 1010 or 133	Lab Instruments and Methods
EE 2000	Electric Circuits
CS 2010/2020 or 201/202/2030	Introduction to Computer Science
EE 2100	Electronics



Neither CS 2020 nor CS/EE 3710 will be offered Fall 1998. EE 3500 has Math 2210 as a prerequisite.

Students must also satisfy the General Education/University requirements, take three courses that satisfy the math/science elective, and complete five CE electives.

This graph illustrates 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. Two of the four courses contained in dashed boxes must be taken. Where not otherwise indicated, courses are offered during both semesters as well as the summer. This graph assumes adequate high school preparation permitting freshman year enrollment in Math 1210/1220, Physics 2210/2220, and Computer Science 2010/2020.

Figure 1.2: Computer Engineering Prerequisites

CS 3500	Software Practice
CS/EE 3700	Digital Design
CS/EE 3710	Computer Design Laboratory
CS/EE 3720	Interfacing Microprocessors & Microcontrollers
CS/EE 3810	Computer Architecture
CS/EE 4710	Computer Engineering Senior Project

(b) Restricted electives. Two of the following four classes must be taken:

EE 3300	Electromagnetics and Transmission Lines
EE 3500	Signals and Systems
CS 3510	Algorithms and Data Structures
CS 5460	Operating Systems

(c) Technical electives. Five additional Computer Science or Electrical Engineering classes at the 3000 level or higher must be taken. Three of the classes must be in one of the following depth tracks.

i. Communications/Controls/Digital Signal Processing
EE 3501 Introduction to Feedback Systems
Two 5000-level or higher courses numbered EE x5xx or EE x6xx

ii. Computer Architecture/Software Systems
CS/EE 5810 Advanced Computer Organization
Two 5000-level or higher courses numbered CS x4xx or CS/EE x8xx

iii. Integrated Circuit Design
CS/EE 5710 Integrated Circuit Design I
Two 5000-level or higher courses numbered CS/EE x7xx

iv. Microwaves/Optics
EE 3310 Engineering Microwaves and Optics
Two 5000-level or higher courses numbered EE x3xx or EE x4xx

v. Robotics/Intelligent Systems
CS 5310 Robotics
Two 5000-level or higher courses numbered CS x3xx

vi. Semiconductor Devices (both classes and labs should be taken)
EE 3101 Electronics II
Two 5000-level or higher courses numbered EE x1xx or x2xx

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

5. **Continuing Performance:** In order to remain in good standing and to graduate, a student is required to maintain a cumulative grade point average of 2.3 or higher, and also to maintain a grade point average of 2.3 in Computer Engineering classes. Each course taken to satisfy the CE requirements listed above must be passed with a grade of C− or better. A student may repeat a course at the 3000 level or above only one time. All CS and EE classes (other than CS 1010 or 110) taken to satisfy the requirements for a Computer Engineering degree must be taken for a letter grade; they may not be taken CR/NC.

   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. Reinstatement requires a petition to the Computer Engineering Committee. Reinstated students proceed under the latest graduation requirements.

   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 CS or EE 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, 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.

1.4 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. The following scholarships are available:

Continuing Student Scholarship. This award is available to sophomore, junior or senior students majoring in Computer Engineering and who are residents of the state of Utah. It is for resident tuition for two semesters. It is expected that there will be one award available each year. To be eligible, students must take at least 12 credit hours per semester. Applications for these scholarships must be submitted to the CE Academic Counselor by March 15.

College of Engineering Scholarships. A few awards are available each year to Computer Engineering majors. These are unrestricted cash awards of $500 to $1,000. To be eligible, students must take at least 8 credit hours per semester. Use the same application as for the Continuing Student Scholarship.

Sperry Rand Scholarship. This scholarship is awarded on the basis of excellence to one junior or senior student majoring in Computer Science or in Computer Engineering. The award is an unrestricted cash prize of approximately $500. To be eligible, students must take at least 8 credit hours per semester. Use the same application as for the Continuing Student Scholarship.

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.

1.5 Employment Opportunities

The University Placement Center 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, and Unisys. Many of our majors take advantage of this valuable opportunity.

Both the CS and EE departments 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 quarterly 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 Placement Center in order to be included on a list supplied to employers. Students not planning to work towards an advanced degree should register with the Placement Center at the beginning of their senior year, since most companies begin interviewing in the autumn quarter.

1.6 Other Information

More information concerning faculty, facilities, and services in the Departments of Computer Science and Electrical 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 information[1] are available on line.

EE 1000 Introduction to Electrical and Computer Engineering (4, S) Prereq: Math 1210; Coreq: EE 1010, MATH 1220, PHYCS 2220.

The basics of analog and digital circuits as an introduction to electrical and computer engineering. Concepts of voltage, current, power, resistance, capacitance, binary numbers, digital coding, and A/D interfacing. Circuit analysis techniques such as Kirchhoff's Laws, branch currents, node voltages, and mesh currents. Thevenin's and Norton's equivalent circuits. Device modeling of simple op amps, diodes, transistors, logic gates, and flip-flops. Extensive use of Matlab as an analysis and design aid.

CS 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. (This course is half of a semester in length, and is offered twice during the fall and spring semesters and once during the summer.)

EE 1010 Introduction to Lab Instruments & Methods (0.5, S) Coreq: EE 1000.

Laboratory instruction on the proper use of electronic measuring instruments, including function generators, voltmeters, and oscilloscopes. Loading and frequency effects.

[1] http://www.acs.utah.edu/student/index.htm

EE 2000 Fundamentals of Electric Circuits (4, F) Prereq: EE 1000, 1010, CS 2010, 2020 or ability to program in a high-level language; PHYCS 2220; Coreq: MATH 2250.

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

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

The first course required for students intending to major in computer science. 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. Selected topics from discrete math that underlie computer science. Extensive programming exercises that involve the application of elementary software engineering techniques.

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

The second course required for students intending to major in computer science. 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. Selected topics from discrete math that underlie computer science. Extensive programming exercises that require the application of elementary techniques from software engineering. (Not offered Fall 1998.)

CS 2030 Introduction to Computer Science III (2, F) Prereq: CS 202.

Material from the new CS 2010–CS 2020 sequence that could not be covered in the old CS 201–CS 202 sequence. This will include some elementary concepts from discrete math, some of the more advanced data structures and algorithms, and algorithm analysis. (This course will be offered once during the fall semester of 1998, and it will not be taught thereafter. It must be taken by all new Computer Science and Computer Engineering majors at that time.)

EE 2100 Fundamentals of Engineering Electronics (4, S) Prereq: EE 2000, PHYCS 2220, MATH 2250..

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.

CS 3100 Models of Computation (3, S) Prereq: CS 2020.

Introduction to the mathematical underpinnings of computer science. Methods for describing and reasoning about hardware and software, including predicate logic, recursion, induction, and combinatorics. Models of sequential computation, including finite-state automata, push-down automata, and Turing machines. Models of concurrent computation, including Petri nets and communicating sequential processes.

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

CS 3200 Scientific Computation (3, F) Prereq: CS 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).

EE 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.

EE 3310 Engineering Electromagnetics and Applications (4, S) Prereq: EE 2000, 3300.

Wave reflection and transmission at plane boundaries, applications in optics, propagation characteristics in waveguides and antenna theory and design including wire and aperture antennas. Numerical techniques including formulation of electromagnetics engineering problems in terms of differential and integral equations and the solution of these equations using the Finite Difference and Method of Moments, respectively.

CS 3500 Software Practice (4, F) Prereq: CS 2020.

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.

EE 3500 Fundamentals of Signals and Systems (4, F) Prereq: EE 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.

CS 3510 Algorithms and Data Structures (3, S) Prereq: CS 3500.

Study of algorithms, data structures, and complexity analysis beyond the introductory treatment from CS 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.

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

Laboratory included. Analysis of systems using Laplace transforms; transfer functions, stability, steady-state responses and transient responses. Feedback control: PID and lead-lag controllers, design using root-locus, and phase-locked loops. Frequency-domain design: Bode plots, filter design, and Nyquist criterion.

CS 3520 Programming Language Concepts (3, F) Prereq: CS 3510.

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. (Not offered Fall 1998.)

CS/EE 3700 Fundamentals of Digital System Design (4, S) Prereq: CS 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.

CS/EE 3710 Computer Design Laboratory (3, F) Prereq: CS/EE 3700, CS/EE 3810.

Student groups design, build, and test a programmable device such as a computer or calculator. (Not offered Fall 1998.)

CS/EE 3720 Analog & Digital Interfacing with Microprocessors & Microcontrollers (4, S) Prereq: CS/EE 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. (Offered Fall 1998, Spring 2000, and every spring semester thereafter. Laboratory included.)

CS/EE 3810 Computer Architecture (4, F) Prereq: CS 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. Includes a two-hour laboratory scheduled during the first week of class.

CS 4500 Software Engineering Laboratory (3, S) Prereq: CS 3500 or CS 4510, senior standing in CS.

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

CS 4510 Software Engineering (3, F) Prereq: Senior standing in CS.

Fundamentals of software engineering, including requirements, specifications, design, implementation, testing, and maintenance. Emphasis includes: software process, software engineering techniques (code and documentation standards, source code management, object-oriented analysis and design), and team development practice. (This course will be offered during Fall 1998 and Fall 1999 and will then be discontinued. It is intended for students who completed the CS 354-355-356 sequence under quarters; CS 3500 and CS 4510 may not both be taken for credit.)

CS/EE 4710 Computer Engineering Senior Project (3, F) Prereq: CS/EE 3720.

Students design microcomputer system that includes RAM, EPROM, and I/O devices. Capstone project for computer-engineering majors. Formal written reports, one or more oral presentations. (Offered Spring 1999, Fall 2000, and every fall semester thereafter.)

CS 4950 Independent Study (Arr.)

CS 4999 Honors Thesis/Project (3) Prereq: Restricted to students in the Honors Program working on their Honors degree.

CS 5100/6100 Foundations of Computer Science (3, F) Prereq: CS 3100, CS 3510.

Advanced examination of fundamental ideas behind algorithms, complexity analysis, mathematical logics, elementary computability, and concurrency formalisms.

EE 5201 Semiconductor Device Physics I (2, 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.

EE 5202 Semiconductor Device Physics II (2, S) Prereq: EE 5201.

Continuation of EE 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.

CS 5210/62120 Advanced Scientific Computing I (3) Prereq: CS 3200, CS 3510, MATH 3160.

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. (Offered every third semester, beginning in Fall 1998.)

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

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

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

EE 5221/6221 Fundamentals of Micromachining Processes (2, F) Prereq: Instructor's consent.

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.

EE 5222/6222 Biomedical Applications of Micromachining (2, S) Prereq: EE 5221/6221.

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.

CS 5300/6300 Artificial Intelligence (3, F) Prereq: CS 3510.

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.

CS 5310/6310 Robotics (3, F) Prereq: CS 1000, MATH 2250. Crosslisted with ME 5220/6220.

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.

CS 5320/6320 Computer Vision (3, S) Prereq: CS 3510, MATH 2210, MATH 2270.

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.

EE 5320 Microwave Engineering I (3, F) Prereq: EE 3300; EE 3310 recommended.

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.

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

EE 5324 Antenna Theory and Design (3, S) Prereq: EE 3310.

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.

EE 5330 Introduction to Microwave Tubes and Electron Devices (3, S) Prereq: EE 3310, 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.

CS 5340/6340 Natural Language Processing (3, S) Prereq: CS 3510.

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.

CS 5350/6350 Machine Learning (3, F) Prereq: CS 3510.

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. (Offered alternate years, beginning Fall 1999.)

EE 5410 Lasers and Their Applications (3, F) Prereq: EE 3310.

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.

EE 5411 Fiberoptic Systems (3, S) Prereq: EE 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.

CS 5460/6460 Operating Systems (3, F) Prereq: CS 3510, CS/EE 3810.

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.

CS 5470/6470 Compiler Principles and Techniques (3, S) Prereq: CS 3510, CS/EE 3810, CS 3100.

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.

EE 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.

CS 5480/6480 Data Communications and Networks (3, F) Prereq: CS 3510, CS/EE 3810.

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, internetwork and transport protocols (e.g., IPv4, IPv6, TCP, UDP, RPC, SMTP), networking infrastructure (e.g., routers, nameservers, gateways), network management, distributed applications, network security, and electronic commerce. Principles are put into practice via a number of programming projects.

EE 5510 Random Processes (3, F) Prereq: EE 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.

CS 5520/6520 Programming Languages and Semantics (3, S) Prereq: CS 3520.

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.

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

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

CS 5530/6530 Database Systems (3, F) Prereq: CS 3510.

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.

CS 5540/6540 Human/Computer Interaction (3, F) Prereq: CS 3520.

Fundamentals of input/output devices, user interfaces, and human factors in the context of designing interactive applications.

EE 5540 Digital Signal Processing (3, F) Prereq: EE 3510.

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.

EE 5550 Survey of Function Approximation Methods (2, S) Prereq: MATH 2210, 2250, 3150.

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.

EE 5551 Survey of Optimization Techniques (2, S) Prereq: MATH 2210, 2250, 3150.

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.

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

EE 5580/6580 Implementations of Digital Signal Processing Systems (3, F) Prereq: EE 5540, CS/EE 5710.

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.

CS 5600/6600 Computer Graphics I (3, F) Prereq: CS 3510, MATH 2250.

Basic display techniques, display devices, vector generation, display processors. Homogeneous coordinates, transformations, and clipping in 2-D. Graphics systems, interactive graphics. Introduction to raster graphics. Some elements of photography as related to computer graphics.

CS 5610/6610 Computer Graphics II (3, S) Prereq: CS 5600/6600.

Representations of 3-D objects, polygons, 3-D visualization techniques, hidden-line and hidden- surface removal, polygon clipping, continuous-tone pictures, color displays, lighting models, the aliasing problem. Some fundamentals of photographing computer-generated gray-scale images.

CS 5630/6630 Scientific Visualization (3) Prereq: CS 3510; CS 3200 or CS 5210 or MATH 5600.

An 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. (Offered every third semester, beginning in Fall 1999.)

CS/EE 5710/6710 Advanced Integrated Circuit Design I (3, F) Prereq: CS/EE 3700.

Project-oriented class for the design of a VLSI circuit using high-level design tools. Use of high-level CAD tools such as Viewlogic, Cascade, and Cadence. Three-student teams design, lay out, and simulate a complete integrated circuit. Teams must conduct design reviews, give progress reports, and prepare final written reports. All projects must meet criteria for MOSIS tiny chips and are submitted for fabrication at MOSIS if students agree to test the parts when they are returned.

CS/EE 5720/6720 Advanced Integrated Circuit Design II (3, S) Prereq: CS/EE 5710/6710, EE 2100.

Introduction to basic concepts of the design of CMOS integrated circuits for students with a wide range of backgrounds. Static and dynamic properties of MOS 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.

CS/EE 5740/6740 Computer-Aided Design of Digital Circuits (3, F) Prereq: CS/EE 3700, CS 3510.

Introduction to theory 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. (Offered alternate years, beginning Fall 1998.)

CS/EE 5750/6750 Synthesis and Verification of Asynchronous VLSI Systems (3, S) Prereq: CS/EE 3700, CS 3510.

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. (Offered alternate years, beginning Spring 2000.)

CS/EE 5810/6810 Advanced Computer Architecture (3, F) Prereq: CS/EE 3700, CS/EE 3810.

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.

CS/EE 5830 VLSI Architecture (3, S) Prereq: CS/EE 3710, CS/EE 3810.

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. (Offered alternate years, beginning Spring 2000.)

CS 5940 Seminar (1-3)

Current topics in computer science. May be repeated for credit.

CS 5950 Independent Study (Arr.)

EE 5950 Undergrad Special Study (1-12, FSU)

CS 5960–5964/6960–6964 Special Topics (Arr.)

The following special topics courses are currently scheduled for the 1998–99 academic year. Contact the faculty member in charge for details.

- **CS 5960/6960 Advanced Compilers** (3, F). Prof. Hsieh.
- **CS 5962 Computers and Law** (2, F). Prof. Hollaar.
- **CS 5963 Advanced Manufacturing** (2,F). Prof. Drake.

EE 5960–5961 Special Topics (1-5, FSU)

CS 6010 Writing Research Proposals (2, S)

Fundamental aspects of writing computer science research proposals, including thesis, dissertation, and grant proposals. Form, style, substance, and marketing of effective proposals will be considered. Emphasis is placed on developing and presenting clear and compelling ideas. Substantial writing and class presentations is required of all participants. (This is a half-semester course.)

CS 6110 Formal Methods for System Design (3, S) Prereq: CS 5100/6100 and CS 5520/6520.

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. (Offered alternate years, beginning Spring 2000.)

CS 6220 Advanced Scientific Computing II (3) Prereq: CS 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. (Offered every third semester, beginning in Spring 1999.)

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

EE 6262 Advanced Optoelectronics (3, S) Prereq: EE 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.

EE 6263 Advanced Classical and Quantum Semiconductor (2, S) Prereq: EE 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.

EE 6264 Advanced Silicon Devices (3, S) Prereq: EE 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.

EE 6265 Semiconductor Processing: Epitaxy (2, S) Prereq: EE 6261 or 5202.

Development of a through, 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.

EE 6266 Advanced Semiconductor Device Characterization (2, S) Prereq: EE 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.

EE 6310 Advanced Electromagnetic Fields (3, F) Prereq: EE 3310.

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.

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

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

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

EE 6340 Numerical Techniques in Electromagnetics (3, S) Prereq: EE 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.

CS 6360 Virtual Reality (3, S) Prereq: CS 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. (Offered alternate years, beginning Spring 1999.)

EE 6420 Fourier Optics and Holography (3, F) Prereq: EE 3310, 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.

EE 6430 Statistical Optics, Interferometry, and Detection (3, F) Prereq: EE 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.

EE 6440 Integrated Optics and Optical Sensors (3, S) Prereq: EE 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.

EE 6450 Quantum Electronics (3, F) Prereq: EE 3310, 5410, PHYCS 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.

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

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

Efficient modulation; the capacity theorem; Shannon bound; signal constellations, lattices; maximum-likelihood sequence detection; maximum-aposteriori 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.

EE 6520 Information Theory and Coding (3, S) Prereq: EE 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.

EE 6521 Error Control Coding (3, S) Prereq: EE 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 aposteriori symbol detection (MAP), soft information processing; iterative decoding, Turbo coding principles. Offered alternate years.

EE 6540 Estimation Theory (3, S) Prereq: EE 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.

EE 6550 Adaptive Filters (3, S) Prereq: EE 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.

EE 6560 Multivariable Systems (3, F) Prereq: EE 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.

EE 6570 Adaptive Control (3, F) Prereq: EE 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.

EE 6580 Implementation of DSP Systems (3, S) Prereq: EE 5540, 5710.

CS 6620 Image Synthesis (3, S) Prereq: CS 5610/6610, CS 6670 MATH 5010.

Using camera and sensor simulation along with physical simulation to generate realistic synthetic images. (Offered alternate years, beginning Spring 1999.)

EE 6640 Advanced Digital Signal Processing I (3, F) Prereq: EE 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.

EE 6641 Advanced Digital Signal Processing II (3, F) Prereq: EE 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

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

CS 6680 Computer-Aided Geometric Design II (3, S) Prereq: CS 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. (Offered alternate years, beginning Spring 2000.)

CS/EE 6820 Parallel Computer Architecture (3, S) Prereq: CS/EE 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. (Offered alternate years, beginning Spring 2000.)

CS 6930–6944 Seminar (1-3)

Current topics in Computer Science. May be repeated for credit.

CS 6950 Independent Study (Arr.)

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

CS 7120 Information-Based Complexity (3, S) Prereq: CS 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. (Offered alternate years, beginning Spring 1999.)

CS 7240 Sinc Methods (3) Prereq: CS 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 1998–99.)

CS 7310 Advanced Robotics (3, S) Prereq: CS/ME 5310/6310 5220/6220. Crosslisted with ME 7230.

This course covers the kinematics, dynamics, and control of robotic manipulators. Projects controlling robots will be an integral part of the course. (Offered alternate years, beginning Spring 2000.)

EE 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, Block's equations, pulse sequences, flow and diffusion phenomena, spectroscopy principles, methodology. Laboratory. Offered alternate years.

EE 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 alogrithms, numerical methods; applications in X-Ray CT, SPECT, PET, and NMR. Laboratory. Offered alternate years.

CS 7460 Advanced Operating Systems (3) Prereq: CS 5460/6460, CS 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. (Offered alternate years, beginning Spring 2000.)