Computer Engineering Undergraduate Handbook

University of Utah
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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.

Students then take eight core courses in electric circuits, electronics, digital system design, computer organization, software engineering, software systems, computer design, and embedded systems. 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. Possibilities include advanced courses in communications, controls, digital signal processing, computer architecture, operating systems, computer networks, 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 curriculum encompasses a general education in mathematics (including discrete math, probability, and statistics), science, and the humanities.

(The latest version of this handbook is available online at `http://www.cs.utah.edu/dept/handbooks`.)

Computer Engineering Program Administration

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Contents

1 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 for admission and successful completion of a graduate degree, if they choose to continue on to graduate school.

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 as a pre-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 first complete the courses required of pre-majors and then apply for full major status. An application should be obtained from the School of Computing web page or Computer Engineering office during the semester when the student expects to complete these requirements. One may not preregister for any upper division classes in Computer Engineering without first being admitted as a full major or a minor. Applications for admission are reviewed at the end of each semester.

To be admitted 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, and either 1220 or 1250
    - Physics 2210
    - Computer Science 1410 and 2420 (formerly 2010 and 2020)
    - Electrical Engineering 1020 and 1270
    - University English writing requirement
2. A grade of CR in CS 1010 (a credit/no-credit class).
3. A cumulative University of Utah grade point average of 2.3 or higher.

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, appropriate grades will be assigned for our use in this calculation. Check with the Computer Engineering Academic Counselor for details.

1.3 Undergraduate Advising

The Computer Engineering Program has an Undergraduate Academic Counselor (Coralee Bernard, MEB 3417, 581-3455, `coralee@cs.utah.edu`) who is available to answer questions regarding schedule plans, registration for Computer Engineering classes, degree requirements, recent Computer Engingeering Committee actions, or any problems the student may be experiencing. Students should visit the Academic Counselor at least once a year to verify that they are on track for graduation. They may drop in or make an appointment to see her during her office hours.

The program also has a Faculty Advisor, who can answer questions about any of the above, as well as more technical issues, such as career decisions and equivalence of transfer classes. Contact the Academic Counselor to find out how to arrange an appointment with the Faculty Advisor.

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 satisfied by either Writing 2010 or ESL 1060 (for students who speak English as a second language).

   (b) The quantitative reasoning requirement is satisfied by Math 1210 and either 1220 or1250, which are required for computer engineering pre-majors.

   (c) Students must take two intellectual explorations courses in each of fine arts, humanities, and social/behavioral sciences. (The two-course requirement in physical and life sciences is automatically satisfied by classes that are required for the major.) *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 1740, History 1700, Honors 2212, or Political Science 1100.

   Incoming engineering students should 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.

   Computer Engineering students should also consider CPSC 1050, Computers in Society, as one of their Social/Behavioral Science General Education classes. The course focuses on the social issues that surround the increasingly pervasive roles that computers play in society.

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

   (a) To satisfy the communication/writing requirement, Computer Engineering majors must take either WRTG 3015 (Professional/Technical Writing), WRTG 3014 (Writing in the Sciences), or WRTG 3012 (Writing in the Social Sciences). Honors 3200 (Writing at a Research University) may be taken by students participating in the

University Honors Program. 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. **Mathematics and Science:** A minimum of nine math and science courses must be taken.

(a) One year of calculus (Mathematics 1210 and either 1220 or 1250)

(b) One year of physics for scientists and engineers (Physics 2210/2220)

(c) A course in discrete mathematics (CPSC 2100)

(d) A course in linear algebra and ordinary differential equations (Mathematics 2250)

(e) A course in advanced calculus (Mathematics 1260 or 2210)

(f) A course in probability and statistics (ECE 3530)

(g) One additional class, chosen from among Biology 1210, Chemistry 1210, Math 3150 (Partial Differential Equations), Math 5600 or Computer Science 3200 (Numerical Analysis), and Physics 3740 (Modern Physics)

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 1.2 summarizes the prerequisites for computer engineering courses.

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

CPSC 1010	Introduction to Unix
ECE 1020	EE Problem Solving with Matlab
ECE 1270	Introduction to Electrical Engineering
CPSC 1410/2420	Introduction to Computer Science I and II
ECE 2270	Electric Circuits
ECE 2280	Electronics
CPSC 3500	Software Practice
CPSC/ECE 3700	Fundamentals of Digital System Design
CPSC/ECE 3710	Computer Design Laboratory
CPSC/ECE 3810	Computer Organization
CPSC/ECE 3991	Junior Seminar
CPSC 4400	Computer Systems
CPSC/ECE 5780	Embedded Systems

(b) Technical electives. Six additional Computer Science or Electrical Engineering classes numbered 3000 or above, totaling at least 18 semester hours, must be taken. CPSC 5010/20 and seminars may not be counted. 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.

(c) Capstone Requirement. One of the following must be completed.

CPSC/ECE 3992/4710	Computer Engineering Pre-project and 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 or in Computer Science.* 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 or in the School of Computing.

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

5. **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
   CPSC/ECE 6810 Computer Architecture
   5000-level or higher courses numbered CPSC x4xx or CPSC/ECE x8xx

   (c) Integrated Circuit Design
   CPSC/ECE 6710 Digital VLSI Design
   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

6. **Continuing Performance:** *All computer engineering, mathematics, science, and writing courses taken to satisfy the requirements listed above must be taken for a grade and must be passed with a C− or better* (except for CPSC 1010, in which a grade of CR is required). A student may repeat such courses only one time.

   In order to remain in good standing and to graduate, a student must maintain a cumulative grade point average at the University of 2.3 or higher, and also maintain a grade point average of 2.3 in computer engineering classes taken at the University. 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 after the first 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 Scholarships

Computer Engineering students are eligible for several different scholarships. Most of these are awarded through either the School of Computing or the Department of Electrical and Computer Engineering. Recipients are selected based upon

	Fall		*Spring*	
Freshman	CPSC 1010†	(0.5)	CPSC 2420†	(4)
	CPSC 1410†	(4)	ECE 1020† *	(1)
	Math 1210†	(4)	ECE 1270† *	(4)
	Writing 2010†	(3)	Math 1220†	(4)
	Gen Ed	(3)	Physics 2210†	(4)
		(14.5)		(17)
Sophomore	CPSC/ECE 3810	(4)	CPSC/ECE 3700	(4)
	ECE 2270	(4)	ECE 2280	(4)
	CPSC 3500	(4)	Math 2250	(3)
	Physics 2220	(4)	Writing 3015	(3)
			Gen Ed	(3)
		(16)		(17)
Junior	CPSC/ECE 3710	(3)	CPSC/ECE 3992	(1)
	CPSC/ECE 3991	(0.5)	CPSC/ECE 5780	(4)
	CPSC 2100	(3)	ECE 3530	(3)
	CPSC 4400	(4)	CE technical elective	(3)
	Math 2210	(3)	Math/science elective	(3)
	Gen Ed	(3)	Gen Ed	(3)
		(16.5)		(17)
Senior	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)
		(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 mathematics; it is not advisable to take Physics 2210 without some previous training in calculus. Note that Math 1210, Writing, and Computer Science 1410 must all be taken during the fall semester in order to complete the required pre-major classes during the first year, unless the student has advanced placement credit. (†Class required of pre-majors.) (* These classes are offered in summer semester if students prefer to take the E-LEAP class in spring.)

Figure 1.1: Example Computer Engineering Degree Program

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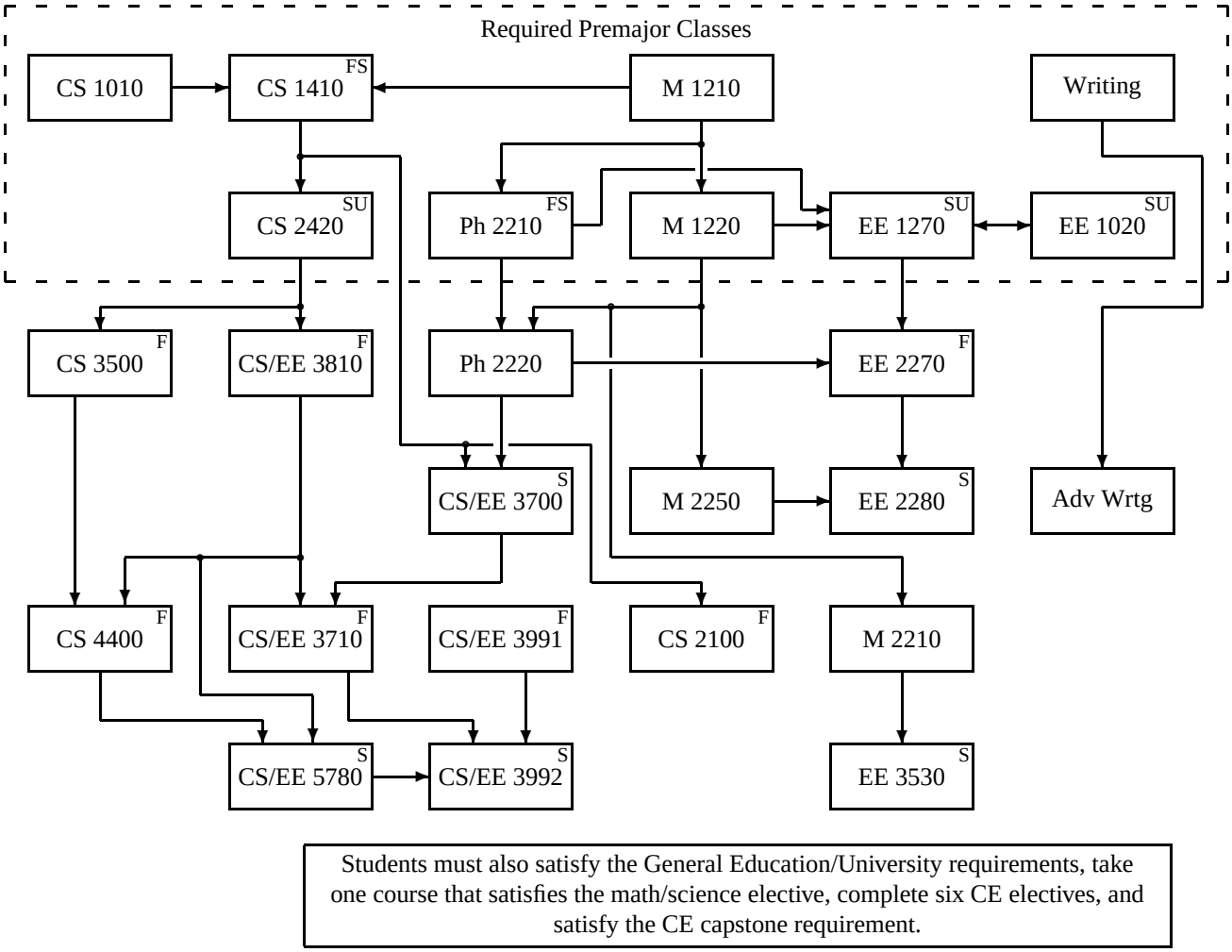
academic performance, rather than financial need. Most are awarded to CE full majors or those students who will become full majors during the following academic year. The following scholarships are available:

School of Computing Scholarships. A few tuition and cash awards are given to Computer Science and Computer Engineering majors each year. Tuition scholarships are available only to Utah residents and cover up to 18 credit hours of resident tuition for two semesters; to be eligible, students must take at least 12 credit hours per semester.

Cash scholarships are available to all CE majors and range in value from $500 to $3,000. They are made possible by generous donations from the School of Computing faculty, the Eccles Foundation, Kiri Wagstaff, and others. To be eligible, students must take at least 9 credit hours per semester.

Applications for these scholarships are available on the web at http://www.cs.utah.edu/students/undergradinfo.shtml or from the School of Computing office (MEB 3190). They must be submitted to the School's office by March 15 of the preceding year.

Department of Electrical and Computer Engineering Scholarships. A few tuition and cash awards are given to Computer Engineering majors each year. Tuition scholarships are available only to Utah residents and cover up to 18



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

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credit hours of resident tuition for two semesters. Cash scholarships are available to all CE majors and range in value from $500 to $4,000; they are made possible by generous donations from the Micron Technology Foundation and others. To be eligible for any of these awards, students must take at least 12 credit hours per semester.

Applications for these scholarships are available from the Department of Electrical and Computer Engineering office (MEB 3280). They must be submitted to that office by February 15 of the preceding year.

The College of Engineering also awards several scholarships (Kennecott, Ariel Berrier, Simon Ramo, and others) to the top students in the college. Students may also apply for financial aid from the College, which each year awards a number of Josephine Beam Educational Scholarships. These are worth approximately $500 and are based on need. Information and applications are available on the web at http://www.coe.utah.edu/current/FA_Scholarship or from the Office of the Dean of Engineering (Kenn 214). Applications must be submitted by February 15 of the preceding year.

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 generally are paid for their work but receive no academic credit.

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, L-3 Communications Systems, Intel, and Micron. Many of our majors take advantage of this valuable opportunity. Students seeking employment should register with the University Office of Career Services[1].

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 on the web[2]. 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 during their junior 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.

Anyone interested in joining this organizations should contact CESAC at `cesac@cs.utah.edu`. Participation, suggestions, and criticisms are solicited.

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.

[1] http://careers.utah.edu
[2] http://www.cs.utah.edu/dept/webforms/current/ugrad-TA.html

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 undergraduates, and the 6000-level version is for honors and graduate students. The two versions of the class will meet together, but extra work will be expected of honors and graduate students.

Courses that have only 6000-level numbers may be taken by graduate and advanced undergraduate students.

Current class schedules and registration information[1] are available on line.

Some elective classes are not offered every year. Check the on-line schedule or the Computer Engineering advisor to see which classes will be offered in upcoming semesters.

CPSC 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, and electronic mail. Self-paced course using online teaching aids.

ECE 1020 EE Problem Solving with Matlab (1, SU) Prereq.: MATH 1050, MATH 1060

Introduction to the field of Electrical Engineering through programming in the Matlab language. Students design various components of a prototype communication system while learning about the following aspects of Matlab: script and function files, math functions, commands for array construction and manipulation, string expressions, logical operators, control flow, and graphics. No prior knowledge of Electrical Engineering is assumed.

CPSC 1050 Computers in Society (3, FS) Social/Behavioral Science Exploration Course

Survey of the social issues that surround the increasingly pervasive roles that computers play in society. Topics include privacy of personal information, encryption and interception of communications, risks posed by unreliable computer systems, freedom of speech in cyberspace, intellectual property as it relates to downloadable media,

[1] http://www.utah.edu/students/catalog.html

computer-based crime, and computers in the workplace. Case studies will focus on computer-related issues of current public interest. No background in computer technology is required or assumed beyond the ability to use a computer to send e-mail, browse the web, and write papers.

ECE 1270 Introduction to Electrical and Computer Engineering (4, SU) 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, capacitance, and inductance. Circuit analysis techniques such as Kirchhoff's Laws, node voltages, and mesh currents. Thevenin's and Norton's equivalent circuits. Simple op-amp and timing circuits. Alternating current and impedance.

CPSC 1410 Introduction to Computer Science I (4, FS) Coreq.: MATH 1210, CPSC 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.

CPSC 2100 Discrete Structures (3, F) Prereq.: CPSC 1410

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 2270 Fundamentals of Electric Circuits (4, F) Prereq.: ECE 1270, 1020; Coreq.: PHYCS 2220

Fundamental electric-circuit techniques, including Kirchhoff's laws, impedance, superposition, phasor transforms, RLC solutions in the time domain, sinusoidal steady-state systems, frequency response, filters, Fourier-series methods, Laplace-transform techniques, transformers.

ECE 2280 Fundamentals of Engineering Electronics (4, S) Prereq.: ECE 2270; Coreq.: MATH 2250

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.

CPSC 2420 Introduction to Computer Science II (4, SU) Prereq.: CPSC 1410

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.

CPSC 3100 Models of Computation (3, F) Quantitatively Intensive B.S. Course. Prereq.: CPSC 2420, CPSC 2100

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

ECE 3110 Engineering Electronics II (4, F) Prereq.: ECE 2280

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.

CPSC 3200 Scientific Computation (3, S) Prereq.: CPSC 2420, 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.: ECE 2280

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.

CPSC 3500 Software Practice I (4, F) Prereq.: CPSC 2420

Meets with CPSC 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 2270, 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.

CPSC 3505 Software Practice II (3, S) Prereq.: CPSC 3500

Meets with CPSC 5020. An in-depth study of traditional software development (using UML) from inception through implementation. The entire class is team-based, and will include a project that uses an agile process.

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

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-date systems, conversion between continuous-time and discrete-time systems.

ECE 3530 Engineering Probability and Statistics (3, S) Prereq.: MATH 2210

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.

CPSC/ECE 3700 Fundamentals of Digital System Design (4, S) Quantitatively Intensive B.S. Course. Prereq.: CPSC 1410 or CPSC 2000, PHYCS 2220

Techniques for reasoning about, designing, minimizing and implementing digital circuits and systems. Combinatorial (logic and arithmetic) and sequential circuits are covered in detail leading up to the design of complete small digital systems using finite state machine controllers. Use of computer-aided tools for design, minimization, and simulation of circuits. Laboratory is included involving circuit implementation with MSI, LSI, and field programmable gate arrays.

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

Working in teams, students employ the concepts of digital logic design and computer organization to design, implement, and test a computing system. Interface I/O devices and develop associated software/firmware. Extensive use of CAD and software tools.

CPSC/ECE 3810 Computer Organization (4, F) Quantitatively Intensive B.S. Course. Prereq.: CPSC 2420 or CPSC 2000

An in-depth study of computer architecture and design, including topics such as RISC and CISC instruction set architectures, CPU organizations, pipelining, memory systems, input/output, and parallel machines. Emphasis is placed on performance measures and compilation issues.

CPSC/ECE 3960 Special Topics (1–4)

Special topics courses are taught every year. Check the on-line schedule for a current listing of offerings.

ECE 3960–3962 Undergraduate Special Topics (1-5)

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

Presentations 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.

CPSC/ECE 3992 Computer Engineering Pre-Thesis/Pre-Project (1, S) Prereq.: CPSC/ECE 3710 and 3991, CE major status; Coreq.: CPSC/ECE 5780

Fundamentals of project planning (scoping, group selection, risk assessment, scheduling, backup planning, strategy, etc.) are covered in the first half of the course. The second half involves student presentations and critique of proposals in progress. The final result of the course will be an approved project or thesis proposal.

CPSC 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.

CPSC 4100 Advanced Algorithms and Data Structures (4, S) Quantitatively Intensive B.S. Course. Prereq.: CPSC 2100, CPSC 2420

Study of algorithms, data structures, and complexity analysis beyond the introductory treatment from CPSC 2420. 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.

CPSC 4400 Computer Systems (4, F) Prereq.: CPSC 3500, CPSC 3810

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.

CPSC 4500 Software Engineering Laboratory (3, S) Prereq.: CPSC 3505, senior standing in Computer Science

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

CPSC 4540 Web Software Architecture (3, S) Prereq.: CPSC 3505

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.

CPSC 4550 Simulation (3, F) Prereq.: CPSC 3505

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.

CPSC/ECE 4710 Computer Engineering Senior Project (3, F) Prereq.: CPSC/ECE 3710, 3992, and 5780

This is the capstone project course for Computer Engineering majors who do not choose to do a thesis. Projects are done in groups and are of the student's choosing. Classroom sessions are devoted to improving presentation skills and serve as peer reviews of the ideas and work done to date. Multiple in-progress oral presentations are required as is a final written project report and a final oral presentation.

CPSC 4950 Independent Study (1–4)

CPSC 4960–4964 Special Topics (1–4)

Special topics courses are taught every year. Check the on-line schedule for a listing of offerings.

ECE 4960–4962 Undergraduate Special Topics (1-5)

CPSC/ECE 4991 Computer Engineering Senior Thesis I (2, F) Prereq.: CPSC/ECE 3992 and approved senior thesis proposal

Students work on original senior thesis project under the direction of their approved thesis advisor. This course along with CPSC/ECE 4992 substitute for CPSC/ECE 4710 (Computer Engineering Senior Project) for students who have chosen to do a thesis.

CPSC/ECE 4992 Computer Engineering Senior Thesis II (2, S) Prereq.: CPSC/ECE 4991

Students work on an original senior thesis project under the direction of their approved thesis advisor, make an oral presentation at the annual student technical conference, and prepare and submit their senior thesis for approval. This course along with CPSC/ECE 4991 substitute for CPSC/ECE 4710 (Computer Engineering Senior Project) for students who have chosen to do a thesis.

CPSC 5100 Foundations of Computer Science (3, S) Prereq.: CPSC 3100, CPSC 4100

Meets with CPSC 6100. A survey of topics in theoretical computer science, focusing on computability and complexity. Turing machines, decidability, relative computability, recursion theorem, non-deterministic TMs, complexity measures, time and space hierarchies, P and NP, NP-completeness, program specification and verification. Undergraduates only.

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.

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) Prereq.: ECE 5201, ECE 5211; 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, S)

Meets with ECE 6221. Introduction to the principles of micromachining technologies. Topics include photolithography, silicon etching, thin film deposition and etching, electroplating, polymer micromachining, and bonding techniques. A weekly lab and a review of micromachining applications is included. Undergraduates only.

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

Meets with ECE 6222. Use of the technologies from the first course in the series (ECE 5221) 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. Undergraduates only.

ECE 5225 Microsystems Design and Characterization (3) Prereq.: Semiconductor Device Physics, Micromanufacturing, Senior status

Meets with ECE 6225. Third in a 3-course series on Microsystems Engineering. This course generalizes microsystems design considerations with practical emphasis on MEMS and IC characterization/physical analysis. Two lectures, one lab per week, plus 1/2 hour lab lecture. Must also register for ME EN 6056 (0-credit lab with fees).

CPSC 5300 Artificial Intelligence (3, S) Prereq.: CPSC 3505

Meets with CPSC 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. Undergraduates only.

CPSC 5310 Robotics (3, F) Cross-listed with MEEN 5220. Prereq.: CPSC 1000, MATH 2250, PHYCS 2210

Meets with CPSC 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. Undergraduates only.

CPSC 5320 Computer Vision (3, F) Prereq.: CPSC 3505, MATH 2210, MATH 2270

Meets with CPSC 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. Undergraduates only.

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

Brief review of transmission line theory and Smith Chart, general theory of waveguides, 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, ABCD parameters, directional coouplers and hybrids, power dividers and combiners, signal-flow graphs for microwave amplifiers, microwave resonators and filters including design considerations, filter design by image parameter method, constant-k and m-derived filters, maximally flat and equal-ripple filters, coupled-line filters, ferrite components. Biweekly laboratory assignments to design, fabricate, and test microstrip circuits: e.g., low and band-pass filters, coupled-line filters, directional couplers, etc., using professional-level computer sofware and network analyzers.

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. Visits to various antenna installations in the Salt Lake valley by groups of three students.

ECE 5325 Wireless Communication Systems (3) Prereq.: ECE 3300, ECE 3500

Introduction to wireless transmission systems. This course will emphasize how individual parameters affect overall system design and performance. Topics include: basic cellular systems and parameters, multi-path channels and modulation techniques.

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

CPSC 5340 Natural Language Processing (3, F) Prereq.: CPSC 3505

Meets with CPSC 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. Undergraduates only.

ECE 5340 Numerical Techniques in Electromagnetics (3, S) Prereq.: ECE 3300

Meets with ECE 6340. 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. Undergraduates only.

CPSC 5350 Machine Learning (3, F) Prereq.: CPSC 3505; CPSC 5300 recommended

Meets with CPSC 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. Undergraduates only.

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.

CPSC 5460 Operating Systems (4, F) Prereq.: CPSC 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.

CPSC 5470 Compiler Principles and Techniques (4, S) Prereq.: CPSC 3100, CPSC 4400

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

CPSC 5480 Computer Networks (3, F) Prereq.: CPSC 4100, CPSC 4400

Meets with CPSC 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, internetwork 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. Undergraduates only.

ECE 5480 Principles of Ultrasound (3) 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.

CPSC 5510 Programming Language Concepts (3, F) Prereq.: CPSC 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 5510 Random Processes (3, F) Prereq.: ECE 3500, ECE 3530

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.

CPSC 5520 Anatomy of a Modern Programming Language (3, S) Prereq.: CPSC 5510

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; memoryless modulation methods: PAM, BPSK, M-PSK, FSK, QAM; message sequences; intersymbol interference (ISI); Nyquist signaling; complex baseband models; noncoherent detection.

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

Meets with CPSC 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. Undergraduates only.

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. Undergraduates only.

CPSC 5540 Human/Computer Interaction (3, F) Prereq.: CPSC 3500

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

ECE 5550 Survey of Function Approximation Methods (3) 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. Undergraduates only.

ECE 5570 Control of Electric Motors (3) 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, S) Prereq.: ECE 5530, CPSC/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. Undergraduates only.

CPSC 5600 Introduction to Computer Graphics (3, S) Prereq.: CPSC 3500, MATH 2250

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.

CPSC 5610 Interactive Computer Graphics (3, F) Prereq.: CPSC 5600

Meets with CPSC 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. Undergraduates only.

CPSC 5630 Scientific Visualization (3, F) Prereq.: CPSC 3505; CPSC 3200 or CPSC 6210 or MATH 5600

Meets with CPSC 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. Undergraduates only.

CPSC/ECE 5720 Analog Integrated Circuit Design (3, S) Prereq.: ECE 3110

Meets with CE 6720. Design of analog and mixed-signal CMOS integrated circuits. Fundamental building blocks for analog circuits, including the basic principles of op amp, current mirror, and comparator design. The basics of sample-and-hold circuits. Students complete integrated circuit design, simulation, layout, and verification using computer-aided design tools. Undergraduates only.

CPSC/ECE 5740 Computer-Aided Design of Digital Circuits (3, S) Prereq.: CPSC/ECE 3700, CPSC 4100

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. Undergraduates only.

CPSC/ECE 5750 Synthesis and Verification of Asynchronous VLSI Systems (3) Prereq.: CPSC/ECE 3700, CPSC 3505

Meets with CE 6750. Introduction to systematic methods for the design of asynchronous VLSI systems from high-level specifications to efficient, reliable circuit implantations. Topics include specification, protocols, graphical representations, synthesis, optimization using timing information, and verification. Undergraduates only.

CPSC/ECE 5780 Embedded System Design (4, S) Prereq.: CPSC/ECE 3810, CPSC 2000 or 4400

Meets with CE 6780. Introduction to issues in embedded system design using microcontrollers. Topics include: microcontroller architecture, memory interfacing, serial and parallel I/O interfacing, analog interfacing, interrupt synchronization, and embedded software. Undergraduates only.

CPSC/ECE 5785 Advanced Embedded Systems (4, F) Prereq.: CPSC/ECE 5780

Meets with CE 6785. This class is about building reliable and efficient embedded systems, with a bias toward software issues and a bias toward whole-system issues. Students complete several projects in C running on ARM-based embedded development boards. The course covers a number of special topics such as embedded software architectures, digital signal processing, feedback control, real-time scheduling, verification and validation, wired and wireless embedded networks, and safety-critical embedded systems. Undergraduates only.

CPSC/ECE 5830 VLSI Architecture (3, S) Prereq.: CPSC/ECE 3700, CPSC/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. Undergraduates only.

CPSC 5950 Independent Study (1–4)

ECE 5950 Undergrad Special Study (1-6) Prereq.: Instructor's consent

CPSC 5960–5969 Special Topics (1–4)

Special topics courses are taught every year. Check the on-line schedule for a listing of offerings.

ECE 5960–5962 Special Topics (1-5)

CPSC 6100 Foundations of Computer Science (3, S) Prereq.: CPSC 3100, CPSC 4100

Meets with CPSC 5100. Graduate and honors students only. Extra work required.

CPSC 6110 Formal Methods for System Design (3, S) Prereq.: CPSC 5100/6100

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.

CPSC 6210 Advanced Scientific Computing I (3, F) Prereq.: CPSC 3200, CPSC 3505, MATH 3150

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.

CPSC 6220 Advanced Scientific Computing II (3, S) Prereq.: CPSC 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 6221 Fundamentals of Micromachining Processes (2, S)

Meets with ECE 5221. Graduate students only. Extra work required.

ECE 6222 Biomedical Applications of Micromachining (2, F) Prereq.: ECE 5221/6221

Meets with ECE 5222. Graduate students only. Extra work required.

ECE 6225 Microsystems Design and Characterization (3)

Meets with ECE 5225. Graduate students only. Extra work required.

CPSC 6230 High Performance Parallel Computing (3, S) Prereq.: Programming in C/C++

Overview of parallel computing; processors, communications topologies and languages. Use of workstation networks as parallel computers. Design of parallel programs: data composition, load balancing, communications and synchronisation. Distributed memory and shared memory programming modules; MPI, PVM, threads. Performance models and practical performance analysis. Case studies of parallel applications.

ECE 6231 Microsensors and Actuators (3) Prereq.: ECE 5221/6221

The course builds on ECE 5221/6221, Fundamentals of Micromachining. Topics include definitions, categorization and application fields of microsensors and actuators, an introduction to solid state physics, piezoresistive sensors, semiconductor-based temperature sensors, magnetoresistive sensors, thermoelectric sensors, photoelectric sensors, micro gas and fluid concentration sensors, molecular diagnostics arrays, and various actuators (relays, micromotors, inkjet printheads, micropumps), sensor packaging and assembly. Registration for a weekly lab (1) is required.

ECE 6232 Microsensors and Actuators Lab (1) Prereq.: ECE 5221/6221; Coreq.: ECE 6231 or 7231

The lab is compulsory when taking ECE 6231 or 7231. The lab will include design and simulation of microsensors and actuators, process design, packaging and assembly, characterization and testing of microsensors and actuators as well as reliability issues. The first part of the lab will focus on the acquirement of additional technological skills and understanding of sensor characteristics. The second part of the lab will lead to the fabrication, characterization and presentation of a variety of fully functional microsensors or actuators. Examples of these are pressure, force, acceleration, gas sensors and inkjet printheads.

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.

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.

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

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.

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 submicron 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 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.

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

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.

CPSC 6300 Artificial Intelligence (3, S) Prereq.: CPSC 3505

Meets with CPSC 5300. Graduate and honors students only. Extra work required.

CPSC 6310 Robotics (3, F) Cross-listed with MEEN 6220. Prereq.: CPSC 1000, MATH 2250, PHYCS 2210

Meets with CPSC 5310. Graduate and honors students only. Extra work required.

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.

CPSC 6320 Computer Vision (3, S) Prereq.: CPSC 3505, MATH 2210, MATH 2270

Meets with CPSC 5320. Graduate and honors students only. Extra work required.

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.

ECE 6330 Microwave Devices and Physical Electronics I (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.

ECE 6331 Microwave Devices and Physical Electronics II (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.

CPSC 6340 Natural Language Processing (3, F) Prereq.: CPSC 3505

Meets with CPSC 5340. Graduate and honors students only. Extra work required.

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

Meets with ECE 5340. Graduate students only. Extra work required.

CPSC 6350 Machine Learning (3, F) Prereq.: CPSC 3505; CPSC 5300/6300 recommended

Meets with CPSC 5350. Graduate and honors students only. Extra work required.

CPSC 6360 Virtual Reality (3, S) Prereq.: CPSC 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.

CPSC 6370 Geometric Computation for Motion Planning (3, F) Prereq.: CPSC 1020, MATH 2250

Geometric computation is the study of practical algorithms for solving queries about geometric properties of computer models and relationships between computer models. Robot motion planning uses these algorithms to formulate safe motion through a modeled environment. In addition, algorithms for geometric computation are used in computer animation, simulation, computer-aided design, haptics, and virtual reality. Topics to be covered in this course are spatial subdivision and model hierarchies, model intersection, distance queries and distance fields, medial axis computations, configuration space, and motion planning. The course will rely on lectures, readings, and projects to provide understanding of current practices in the field.

CPSC 6380 Multiagent Systems (3, S) Prereq.: knowledge of programming, data structures, processes, language syntax, and either Matlab or C

Covers fundamental notions of (1) software agents, including: autonomy, communication, persistence, and intelligence; and (2) multiagent systems, including: communication standards, cooperation, competition and coordination. Methods will be applied to a practical application (usually in Matlab or C).

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.

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.

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.

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

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.

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

Compilation of modern languages. Optimization techniques, register allocation and instruction scheduling, garbage collection, exception handling. Linkers and late-stage compilation and optimization.

CPSC 6480 Computer Networks (3, F) Prereq.: CPSC 4100, CPSC 4400

Meets with CPSC 5480. Graduate and honors students only. Extra work required.

CPSC 6490 Network Security (3, S) Prereq.: CPSC 5480/6480

Comprehensive introduction to the principles and practices of network security, especially Internet Security. Topics to be covered include: cryptography, authentication, access control, web security, denial-of-service, digital pests, anonymity, and intrusion detection. Existing network security standards will be used for case studies. Includes laboratory practice.

CPSC 6510 Functional Programming (3, F) Prereq.: CPSC 3100, CPSC 5510

Practical programming with functional language (e.g., Scheme, ML, Haskell) and functional techniques (e.g., fold operators, continuation-passing style, monads, parametric polymorphism). No previous experience with functional language is required. Course work includes writing programs, presenting programs in class, and critiquing peer programs.

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-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.

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 aposteriori symbol detection (MAP), soft information processing; iterative decoding, Turbo coding principles.

CPSC 6530 Database Systems (3, F) Prereq.: CPSC 3500

Meets with CPSC 5530. Graduate and honors students only. Extra work required.

ECE 6530 Digital Signal Processing (3, F) Prereq.: ECE 3510

Meets with ECE 5530. Graduate students only. Extra work required.

CPSC 6540 Human/Computer Interaction (3, F) Prereq.: CPSC 3500

Meets with CPSC 5540. Graduate and honors students only. Extra work required.

ECE 6540 Estimation Theory (3, S) Prereq.: ECE 5510, 5530

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.

ECE 6550 Adaptive Filters (3, S) Prereq.: ECE 5510, 5530

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.

ECE 6551 Survey of Optimization Techniques (3) 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.

ECE 6552 Survey of Function Approximation Methods (3) Prereq.: MATH 2210, 2250, 3150

Meets with ECE 5550. Graduate students only. Extra work required.

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.

ECE 6561 Robust Multivariable Control (3, S) Prereq.: ECE 5310; Coreq.: ME EN 5210 or equivalent

Analysis and control of uncertain systems. Representation of uncertain systems and their performance requirements using linear fractional transformation (generalized plant framework). Design of robust controllers, including frequency-weighted linear quadratic regulators, minimax, H-infinity and H-2 synthesis methods.

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.

ECE 6580 Implementations of Digital Signal Processing Systems (3, S) Prereq.: ECE 5530, 5710

Meets with ECE 5580. Graduate students only. Extra work required.

CPSC 6610 Advanced Computer Graphics I (3, F) Prereq.: CPSC 5600

Meets with CPSC 5610. Graduate and honors students only. Extra work required.

CPSC 6620 Ray Tracing (3, S) Prereq.: CPSC 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.

CPSC 6630 Scientific Visualization (3, F) Prereq.: CPSC 3505; CPSC 3200 or CPSC 6210 or MATH 5600

Meets with CPSC 5630. Graduate and honors students only. Extra work required.

ECE 6640 Advanced Digital Signal Processing I (3, F) Prereq.: ECE 5510, 5530

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.

ECE 6641 Advanced Digital Signal Processing II (3, S) Prereq.: ECE 5510, 5530, 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.

CPSC 6670 Computer-Aided Geometric Design I (3, F) Prereq.: MATH 2210, MATH 2250, CPSC 3505; Coreq.: CPSC 5600

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.

CPSC 6680 Computer-Aided Geometric Design II (3) Prereq.: CPSC 6670

Project based on material covered in CPSC 6670.

CPSC/ECE 6710 Digital VLSI Design (4, F) Prereq.: CPSC/ECE 3700

Introduction to basic concepts of the design of CMOS integrated circuits. Static and dynamic properties of CMOS circuits, composite layout of CMOS circuits, and modeling of transistors. Commonly encountered CMOS circuits. Students complete design, composite layout, and simulation of an integrated circuit project using computer-aided design tools.

CPSC/ECE 6712 Digital IC Projects Testing (1, F) Prereq.: CPSC/ECE 6710

This course is designed for students who fabricated an integrated circuit in CPSC/ECE 6710 or 6770. Students will test their chiips independently and report on the experimental results.

CPSC/ECE 6720 Advanced Integrated Circuit Design II (3, S) Prereq.: ECE 3110

Meets with CE 5720. Graduate and honors students only. Extra work required.

CPSC/ECE 6721 Analog Integrated Circuits Lab (1, S) Coreq.: CPSC/ECE 6720

Optional lab that accompanies CP SC/ECE 5720/6720. Students will test and characterize transistors, circuits, and systems on modern CMOS chips.

CPSC/ECE 6722 Analog Integrated Circuits Project Testing (1, F) Prereq.: CPSC/ECE 6720

This course is designed for students who fabricated an integrated circuit in CP SC/ECE 5720/6720. Students will test their chips independently and report on the experimental results.

CPSC/ECE 6740 Computer-Aided Design of Digital Circuits (3, S) Prereq.: CPSC/ECE 3700, CPSC 4100

Meets with CE 5740. Graduate and honors students only. Extra work required.

CPSC/ECE 6750 Synthesis and Verification of Asynchronous VLSI Systems (3, F) Prereq.: CPSC/ECE 3700, CPSC 3505

Meets with CE 5750. Graduate and honors students only. Extra work required.

CPSC/ECE 6760 Modeling and Analysis of Biological Networks (3, F) Prereq.: Background in molecular or cell biology or formal modeling.

Introduction to methods for modeling and analyzing biological networks such as genetic regulatory networks, metabolic networks, and signal transduction networks. A particular emphasis will be given to methods inspired by models used by engineers for circuit analysis. Other topics include: stochastic analysis using Monte Carlo methods, differential equation models, Bayesian network models, flux balance analysis, learning methods, pathway databases, and synthesized gene circuits.

CPSC/ECE 6770 Advanced Digital VLSI Systems Design (3) Prereq.: CPSC/ECE 6710 and instructor permission

This course addresses advanced issues in VLSI design, covering the following topics: design methodologies and IP design, CMOS circuit scaling, advanced logic circuit styles, noise sources and signal integrity in digital design, design techniques for dynamic and static power reduction, power supply issues, interconnect analysis, clocking and synchronization, process variation, and performance verification. Students are expected to complete a substantial design project as part of the course, which involves extensive use of CAD tools.

CPSC/ECE 6780 Embedded System Design (4, S) Prereq.: CPSC/ECE 3810, CPSC 2000 or 4400

Meets with CE 5780. Graduate students only. Extra work required.

CPSC/ECE 6785 Advanced Embedded Systems (4, F) Prereq.: CPSC/ECE 5780/6780

Meets with CE 5785. Graduate students only. Extra work required.

CPSC/ECE 6810 Computer Architecture (3, F) Prereq.: CPSC/ECE 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.

CPSC/ECE 6830 VLSI Architecture (3, S) Prereq.: CPSC/ECE 3700, CPSC/ECE 3810

Meets with CE 5830. Graduate and honors students only. Extra work required.

CPSC 6960–6969 Special Topics (1–4)

Special topics courses are taught every year. Check the on-line schedule for a listing of offerings.

ECE 6960–6962 Special Topics (1-5)

CPSC 7120 Information-Based Complexity (3) Prereq.: CPSC 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.

ECE 7231 Microsensors and Actuators (3) Prereq.: ECE 5221/6221

The course builds on ECE 5221/6221, Fundamentals of Micromachining. Topics include definitions, categorization and application fields of microsensors and actuators, an introduction to solid state physics, piezoresistive sensors, semiconductor-based temperature sensors, magnetoresistive sensors, thermoelectric sensors, photoelectric sensors, micro gas and fluid concentration sensors, molecular diagnostics arrays, and various actuators (relays, micromotors, inkjet printheads, micropumps), sensor packaging and assembly. Registration for a weekly lab (1) is required.

CPSC 7240 Sinc Methods (3, S) Prereq.: CPSC 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.

CPSC 7250 Advanced Topics in Scientific Computing (3, F) Prereq.: CPSC 6220

In-depth study of research topics of current interest in scientific computing. Topics will typically have been surveyed in CPSC 6210 and 6220. This course can be repeated for credit since the focus will be changed from semester to semester.

CPSC 7310 Advanced Robotics (3) Cross-listed with MEEN 7230. Prereq.: CPSC 5310/6310 or ME EN 5220/6220

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

ECE 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.

CPSC 7320 System Identification for Robotics (3) Prereq.: CPSC 5310/6310 or ME EN 5220/6220

Modeling and identification of the mechanical properties of robots and their environments. Review of probability and statistics. Parametric versus nonparametric estimation. Linear least squares parameter estimation, total least squares, and Kalman filters. Nonlinear estimation and extended Kalman filters. State estimation. Specific identification methods for kinematic calibration, inertial parameter estimation, and joint friction modeling.

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

The course focuses on the problem of three-dimensional (3D) image reconstruction from line integrals, which constitute a mathematical model of measurements in computed tomography (CT), and particularly x-ray computed tomography. Analytical and iterative reconstruction methods are investigated for various geometries of data acquisition. A critical goal is to provide the student with the essential tools required to understand papers on tomographic image reconstruction, from x-ray CT to emission CT, and also with a clear understanding of how efficient and accurate reconstruction algorithms are designed, using the Fourier slice theorem and backprojection techniques. MATLAB laboratories and a computer project are given in support of the theory.

CPSC 7460 Distributed Operating Systems (3) Prereq.: CPSC 5460, CPSC 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.

CPSC 7520 Programming Language Semantics (3, S) Prereq.: CPSC 3100, CPSC 5510

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 7520 Information Theory (3, S) Prereq.: ECE 5510, ECE 5520

Concept of information and uncertainty; source and channel models; entropy and its properties; relative entropy; mutual information; Shannon's source coding theorem; the Asymptotic Equipartitioning Property (AEP); concepts of source codes; Huffman code; arithmetic coding; variable to fixed source codes; typical sequences; rate distortion theory; channel coding; Shannon's channel coding theorem.

CPSC 7640 Image Processing (3, S) Prereq.: CPSC 2420, MATH 2250

An introductory course in processing grey-scale and color images that covers both mathematical funadmentals and implementation. It introduces students to the basic principles of processing digital signals and how those principles apply to images. These fundamentals include sampling theory, transforms, and filtering. The course also covers a series of basic image-processing problems including enhancement, reconstruction, segmentation, feature detection, and compression. Assignments include several projects with software implementations and analysis of real data.

ECE 7640 Advanced Digital Signal Processing I (3, F) Prereq.: ECE 5510, ECE 5530

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.

ECE 7641 Advanced Digital Signal Processing II (3, S) Prereq.: ECE 5510, ECE 5530

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.

CPSC 7650 Realistic Image Synthesis (3, F) Prereq.: CPSC 6620, CPSC 6670, MATH 5010

Using camera and sensor simulation along with physical simulation to generate realistic synthetic images.

CPSC/ECE 7810 Advanced Computer Architecture (3, S) Prereq.: CPSC/ECE 6810

Issues in the design of modern microprocessors, with emphasis on current research topics in the field. Offered in alternate years.

CPSC/ECE 7820 Parallel Computer Architecture (3, S) Prereq.: CPSC/ECE 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 in alternate years.

CPSC 7960–7969 Special Topics (1–4)

Special topics courses are taught every year. Check the on-line schedule for a listing of offerings.

ECE 7960 Special Topics (1-5)