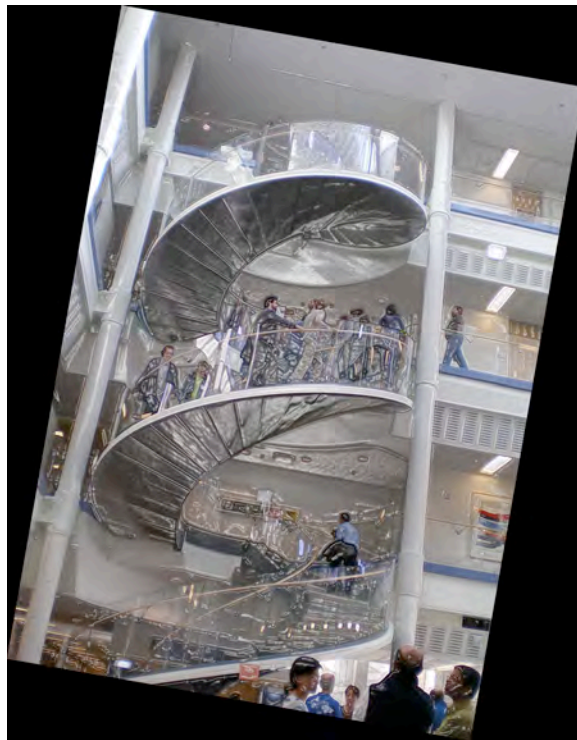




GRADUATE STUDY IN COMPUTER SCIENCE AND ENGINEERING

Computer Science and Engineering Division
The University of Michigan
2260 Hayward
Ann Arbor, Michigan 48109-2121



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TABLE OF CONTENTS

1. OVERVIEW OF THE CSE GRADUATE PROGRAMS	4
2. INTERNET RESOURCES	5
3. MASTER'S DEGREE REQUIREMENTS	6
3.1. CSE Requirements (Master's track)	6
3.1.2. Course Equivalency	7
3.1.3. Cognate Requirement.....	7
3.1.4. Transfer of Credit.....	7
3.1.5. Master's Thesis Option	8
3.2. Advisor	8
3.3. Masters Plan of Study	8
3.4. Applying for Graduation with the Masters Degree	8
3.5. Transfer from the Masters Track to the Ph.D. Program	8
4. Ph.D. DEGREE REQUIREMENTS	9
4.1. CSE Requirements (Ph.D. Track)	9
4.2. Ph.D. Advisor	9
4.3. Qualification	9
4.3.1. Ph.D. Kernel Coursework.....	9
4.3.2. Area Coursework Requirement for the Ph.D.	11
4.3.3. Directed Study and Research Potential	12
4.3.4. Preliminary Examination.....	12
4.4. Candidacy	13
4.5. Dissertation	13
4.5.1. Dissertation Committee	13
4.5.2. Thesis Proposal	14
4.5.3. Dissertation and Final Defense	14
5. Ph.D. TRACK TIMETABLE	14
6. NON-DEGREE (NCFD) STUDENTS	16
7. POLICY FOR DROPPING COURSES	16
8. CSE COURSES	16
Note: Seminar and independent study course cannot be used toward the 500 level requirement	17
9. Electrical Engineering and Computer Science Courses	18
10. ADDITIONAL INFORMATION AND FORMS	43

1. OVERVIEW OF THE CSE GRADUATE PROGRAMS

At the Undergraduate Level: Bachelor's degrees are offered in Computer Engineering, Computer Science, and Electrical Engineering. The degree in Computer Science is offered under the rules of the College of Literature, Science and the Arts and constitutes an LSA degree. The degrees in Computer Science in Engineering, Computer Engineering and Electrical Engineering are offered under the rules of the College of Engineering and each constitutes an Engineering degree.

At the Graduate Level: All graduate degrees are offered under the rules of the Rackham School of Graduate Studies. This document covers the Masters and Doctoral Degrees in Computer Science and Engineering.

The CSE Graduate Committee is the governing committee for all CSE academic degrees and students. The CSE Programs fall under the College of Engineering Honor Code, please see the College website for details (<http://www.engin.umich.edu/>).

M.S. and M.S.E. in Computer Science and Engineering

The Graduate Program in CSE is organized into five broad areas: (1) hardware systems, (2) intelligent systems, (3) software systems, (4) theory of computation, and (5) VLSI and CAD. The program is administered by the Computer Science and Engineering Division of the Department of Electrical Engineering and Computer Science. In addition to satisfying the rules of the CSE Graduate Program (covered in this document), a student must also satisfy the regulations of the Rackham School of Graduate Studies, the College of Engineering, for details see the Rackham Website. <http://www.rackham.umich.edu/>

The M.S.E. and M.S. degree programs are identical except for admission requirements. Students desiring admission to the M.S.E. program must have an earned bachelor's degree in computer engineering. Application procedures and the principle requirements for the M.S.E. and M.S. degree programs are described in detail on our web page, <http://www.eecs.umich.edu>.

A student must earn at least 30 credit hours of graduate level coursework, of which at least 24 hours must be technical courses. At least 15 hours must be CSE coursework at the 500 level or higher (excluding credit hours earned in individual study, research or seminar courses). The student must also satisfy course requirements in "kernel" areas of software, hardware, artificial intelligence and theory. A maximum of six (6) credit hours of individual study, research and seminar courses will be accepted toward the master's degree. The VLSI and CAD concentration has different course requirements. It usually takes 1 1/2 to 2 years to complete the masters degree (3-4 full terms).

The Program requires that the Grade Point Average received in CSE coursework must be at least 5.0 based on Rackham's 9.0 scale. An individual course grade of B- or better (which is 4.0 or better on Rackham's 9.0 scale) is required for the credit hours received in any course to be counted towards any master's degree requirement. A master's thesis is optional. Credit hours transferred may be applied to meet any master's degree requirement except the 15 credit hours of 500 level CSE coursework required. (Rackham specifies limitations to the circumstances under which credits may be transferred. See the *Rackham Graduate School Academic Policies*. <http://www.rackham.umich.edu/OARD/>) Courses of an insufficiently advanced level, or which substantially duplicate in level and/or content courses already completed by the student, may not be counted as meeting any master's degree requirements.

Ph.D. in Computer Science and Engineering

The doctoral degree in Computer Science and Engineering is conferred by the Rackham Graduate School in recognition of marked ability and scholarship in some relatively broad field of knowledge, plus the demonstrated ability to carry out independent research yielding significant original results.

The doctoral program proceeds in three stages: (1) qualification (consisting of an area examination, required kernel coursework, directed study and preliminary examination) (2) candidacy (there are both departmental and Rackham requirements for achieving candidacy) and (3) dissertation (writing and defense of the dissertation). Candidacy signifies that course work is essentially completed and some research has been started. Successful completion and defense of the doctoral dissertation marks the completion of the requirements for the Ph.D. degree.

2. INTERNET RESOURCES

The *Rackham Student Handbook* and the *Engineering College Bulletin* are among the numerous UM publications available on-line. The *Rackham Student Handbook* gives details about the Ph.D. degree requirements imposed by the Graduate School, and should be consulted by all Ph.D. students, particularly in regard to questions about residency, fees, cognates, and dissertation committee eligibility. All EECS course descriptions are available on the web as well at <http://www.eecs.umich.edu/eecs/courses.html>.

The EECS website is <http://www.eecs.umich.edu>

The Rackham website is <http://www.rackham.umich.edu>

The College of Engineering website is <http://www.engin.umich.edu/>

3. MASTER'S DEGREE REQUIREMENTS

3.1. CSE Requirements (Master's track)

A student must satisfy both the General Master's Degree Requirements of the Rackham School of Graduate Studies, as specified in the *Rackham Bulletin*, and the College of Engineering Regulations as specified in the **College of Engineering Bulletin**. (Both of these publications are available at the websites listed above.)

In addition, the student must satisfy all CSE requirements as follows:

1. Thirty (30) **credit hours** of graduate level courses must be completed.
2. At least twenty-four (24) credit hours in **technical coursework** must be earned.
3. At least fifteen (15) credit hours of **CSE coursework at the 500 level** or higher must be earned. Credit hours earned in other departments or universities and credit hours earned in individual study, research or seminar courses cannot be counted towards this requirement. Three (3) hours of EECS 599 (directed study with a CSE faculty member) may be counted, and certain EECS 598 (special topics) courses that are intended to become regular courses may be used to satisfy this requirement, *these must have prior approval*. Credit hours earned in other departments or universities and credit hours earned in EECS 599, other individual study, research or seminar courses cannot be counted toward this requirement. In the VLSI and CAD kernel, one of either EECS 522 or EECS 523 may be used toward the 500-level requirement if taken to fulfill a VLSI and CAD kernel requirement.
4. A maximum of six (6) credit hours of **individual study**, research and seminar courses (EECS 598, EECS 699 and similar courses) will be accepted toward the master's degree.
5. An individual course grade of B- or better, which is 4.0 or better on Rackham's 9.0 scale, is required for the credit hours received in any course to be counted towards any master's degree requirement. Rackham requires the overall GPA among all courses applied to the master's degree to be at least 5.0 based on Rackham's 9.0 scale. In addition to this, the CSE Program requires that the Grade Point Average received in CSE coursework must be at least 5.0 based on Rackham's 9.0 scale. (No letter-graded courses taken as S/U may be used toward any degree requirement.)
6. Courses of insufficiently advanced level, or which substantially duplicate in level and content courses already completed by the student may not be counted as meeting any master's degree requirement. Also please note that courses such as 496, 498, 499 are not approved for credit toward the master's degree.

The CSE Master's degree program requires students to complete certain **"master's kernel" course requirements**. The purpose of the kernel is to give the student broad training in the major areas of computer science and engineering. Students who enter without an undergraduate engineering degree receive an M.S. degree. Students who enter with an undergraduate engineering degree have a choice of either the M.S. or M.S.E. degrees.

One course must be taken from each of the following lists of **master's kernel courses** for those in the hardware, intelligent systems, software, or theory concentrations (from a, b, c, and d):

a. *Hardware*: One of the following: EECS 427 or EECS 478 or EECS 470 or EECS 527 or EECS 570 or EECS 573 or EECS 577 or EECS 578 or EECS 579 or EECS 583 or EECS 627

b. *Intelligent Systems*: EECS 492 or EECS 543

c. *Software*: One of the following: EECS 482 or EECS 483 or EECS 484 or EECS 485 or EECS 489 or EECS 571 or EECS 582 or EECS 583 or EECS 584 or EECS 588 or EECS 589 or EECS 590 or EECS 591

d. *Theory*: EECS 574 or EECS 575 or EECS 586.

The VLSI and CAD master's kernel differs from the other areas as follows:

e. Students are required to take EECS 427 and EECS 627.

In addition, students must complete two of the four master's kernel options listed above (a, b, c, or d). Please note that EECS 427 and/or EECS 627 cannot be used to fulfill the hardware kernel option. One of the chosen 500-level courses must be from the following list: EECS 522 or EECS 523, EECS 527, EECS 578, EECS 579. If you are in the VLSI and CAD area, you must complete all VLSI and CAD master's requirements.

3.1.2. Course Equivalency

Courses taken at another university that are equivalent in level and content may be used to fulfill one or more of the kernel course requirements. In general, equivalency does not fulfill any other degree requirements, in particular, credit-hour requirements. Forms are available in the CSE Graduate Office or online <http://www.eecs.umich.edu/eecs/graduate/cse/csegradpage.html>.

3.1.3. Cognate Requirement

A student may satisfy the cognate requirement (at least four (4) hours of graduate-level course work) by taking course(s) associated with another EECS program (not his/her own), by taking course(s) outside the department, or by a mixture thereof. Courses taken from other programs cannot overlap in content with computer related material. Any course in question must have prior approval of the CSE Graduate Committee. In the VLSI and CAD kernel, one of either EECS 522 or EECS 523 may be used toward the 500 level requirement if it is taken to fulfill a VLSI and CAD kernel requirement, neither may be used toward the cognate requirement.

3.1.4. Transfer of Credit

Credit hours transferred may be applied to meet any master's degree requirements except the 15 credit hours of 500 level CSE coursework. (Rackham specifies limitations to the circumstances under which credits may be transferred. See the *Rackham Student Handbook* <http://www.rackham.umich.edu/OARD/>).

3.1.5. Master's Thesis Option

The option of writing a Master's thesis is available to master's students in good academic standing. A student wishing to exercise this option may initiate the process by taking the following two steps. He/she must: a) find a CSE faculty member willing to serve as thesis advisor; b) enroll under the master's thesis course number (EECS 698) for one to six credit hours. These credit hours may be spread over more than one term, and are graded on an S/U basis.

The thesis advisor is responsible for supervising the work of the master's thesis project, and choosing the master's thesis committee. This committee shall consist of the thesis advisor who serves as chair, and two additional faculty members, and must be approved by the CSE Graduate Committee. At least two of the three thesis committee members must be regular CSE faculty.

The student must write and deposit with the department a written thesis whose format is substantially consistent with the Rackham format requirements for theses. An oral presentation and defense of the thesis before the thesis committee is also required. Each member of the thesis committee must submit a written report on the thesis, and approval of the thesis by all members is required.

3.2. Advisor

Each incoming graduate student is assigned an academic advisor (a faculty member in the CSE program). The advisor may subsequently be changed by mutual agreement. Forms are available in the CSE Graduate Office or online

<http://www.eecs.umich.edu/eecs/graduate/cse/csegradpage.html>.

3.3. Masters Plan of Study

In consultation with the advisor, each student must submit an "MS Study Plan" (approved by his/her advisor) during the first term of enrollment. This plan must contain a listing of the courses the student intends to take to satisfy the degree requirements and must constitute a coherent program at an appropriate level. The MS Plan of Study is intended as a guide to the student and program advisor. **Final responsibility for ensuring that degree requirements are satisfactorily met rests with the student.** Forms are available in the CSE Graduate Office or online

<http://www.eecs.umich.edu/eecs/graduate/cse/csegradpage.html>.

3.4. Applying for Graduation with the Masters Degree

At the beginning of the term in which you expect to receive your masters degree you will need meet with Dawn Freysinger, CSE Graduate Student Coordinator, and review your academic record. To do so you need to bring: a) a copy of the completed diploma application (Rackham requires these to be submitted on-line, so you will need to bring a printed copy with you when you meet with Dawn); b) an approved and current Masters Plan of Study (if an up to date version is not on file in the CSE graduate office) Forms are available in the CSE Graduate Office or online

<http://www.eecs.umich.edu/eecs/graduate/cse/csegradpage.html>.

You must have this meeting for your degree to be processed (please do not hand in the forms without meeting with Dawn). You must complete the above procedure by at least one week before the posted Rackham deadline for submission.

3.5. Transfer from the Masters Track to the Ph.D. Program

Students currently in the master's track that wish to transfer to the Ph.D. track should submit an application for admission to the Ph.D. Program. The deadline for applying for Fall Term is March 1. General information about the application process, including a link to the Rackham online application site, is available at <http://www.cse.umich.edu/eecs/graduate/cse/apply/>. You will need to submit the application, a statement of purpose, and arrange for letters of recommendation.

Given that you are already in our program, it is expected you will have recommendation letters from

Michigan faculty. Further, your application must be sponsored by a particular CSE faculty member who has advised you on a substantial research project and is willing to supervise your PhD research. Your application will be evaluated on the overall record, with special attention to performance in the CSE MS program and demonstrated research potential at Michigan.

4. Ph.D. DEGREE REQUIREMENTS

4.1. CSE Requirements (Ph.D. Track)

Students should note carefully the general requirements for graduate studies stated on, <http://www.rackham.umich.edu/OARD/> as well as the requirements stated in this brochure. It is the student's responsibility to ensure that all requirements are satisfactorily met.

The doctoral program proceeds in three stages:

(1) Qualification (consisting of required area qualification coursework, required Ph.D. kernel coursework, directed study and preliminary examination);

(2) Candidacy (meeting some additional departmental and Rackham requirements for achieving candidacy);
and

(3) Dissertation (writing, thesis proposal, and defense of the dissertation). Candidacy signifies that course work is essentially complete and some research has been started. Successful completion and defense of the doctoral dissertation marks completion of all requirements for the Ph.D. degree.

4.2. Ph.D. Advisor

An incoming graduate student with a relevant master's degree will be assigned an academic advisor (a faculty member in the CSE program) in his/her area of interest. Students already in the CSE master's degree program may continue with the same academic advisor. A student's research advisor, chosen through mutual agreement with the student and the faculty member, will guide and counsel the student on the planning for, and completion of, the Ph.D. degree. The advisor (academic and/or research) may subsequently change by mutual agreement. Forms are available in the CSE Graduate Office or online

<http://www.eecs.umich.edu/eecs/graduate/cse/csegradpage.html>.

4.3. Qualification

Qualification is based on all of the following which must be successfully completed by each students' individual qualification deadline:

1. "Ph.D. Kernel" Coursework in CSE.
2. "Area" Coursework in the students' major area.
3. Directed Study Project. (3 hrs. of course EECS 599)
4. Preliminary Oral Examination ("Prelim") based on the students' Directed Study Project.

Once all the above requirements for Qualification have been met, a decision whether the student is qualified to continue in the Ph.D. Program is made by vote of the CSE Faculty.

4.3.1. Ph.D. Kernel Coursework

The student must complete all essential coursework in several technical areas, including at least 36 hours of relevant graduate level courses beyond the Bachelor's Degree. No courses in which the

student has received a grade of less than B– may be counted toward these 36 credit hours. The student must have a 6.5 GPA overall and a 6.5 GPA for all CSE courses. Students without a relevant master's degree must complete all requirements for a master's degree in Computer Science and Engineering. (No letter graded courses taken as S/U may be used toward any degree requirement.)

The student must also complete certain **"kernel" coursework for the Ph.D.**, which includes one kernel course (in some cases, two courses) in each technical area, as determined by the faculty in that area.

a) Hardware: EECS 427 or EECS 470 or EECS 478 or EECS 527 or EECS 570 or EECS 573 or EECS 577 or EECS 578 or EECS 579 or EECS 583 or EECS 627

b) Intelligent Systems: EECS 492

c) Software: (must complete one 500 level course or two 400 level courses from this list) EECS 482, EECS 483, EECS 484, EECS 485, EECS 489, EECS 571, EECS 582, EECS 583, EECS 584, EECS 588, EECS 589, EECS 590, EECS 591

d) Theory: EECS 574 or EECS 575 or EECS 586.

The VLSI AND CAD Ph.D. kernel differs from the other areas as follows:

e). Students are required to take EECS 427 and EECS 627.

In addition, students must complete two of the four kernel options listed above (a., b., c., d). Please note that EECS 427 and/or EECS 627 cannot be used to fulfill the hardware kernel option. If you are in the VLSI and CAD kernel, you must take all qualification options in VLSI and CAD.

All Ph.D. kernel courses must be completed with a grade of B+ or better within 3 full terms (1 1/2 years) for a student with a relevant Master's degree and 4 full terms for all other students. Courses taken at another university that are equivalent in level and content *may* fulfill one or more of these requirements. Application forms to request an "equivalency" decision for courses taken elsewhere are available in the CSE Graduate Office or online

<http://www.eecs.umich.edu/eecs/graduate/cse/csegradpage.html>

4.3.2. Area Coursework Requirement for the Ph.D.

The "area" coursework requirement is unique in each of the five CSE areas. You must fill out the qualification sign up sheet at the appropriate time stating the courses that you have successfully taken to complete the Area Coursework Requirement.

In the Hardware, Software and Theory areas an exception may be made for students who have taken a course from another university that has been approved as equivalent to one in the above list. In such a case, the faculty who teach the course will give an oral exam to determine whether or not the student has knowledge equivalent to an A, and the results will be indicated on the equivalency form. Equivalency can be granted for at most one course.

The various area requirements are listed below:

Intelligent Systems Area Coursework Requirement:

Students must complete the kernel of EECS 492 by taking the course or through equivalency. A grade of A- or above must be achieved in EECS 592 which should be taken in the first year of study and one of the following list of courses. If an A- is not achieved, the course can be retaken one time before the qualification deadline.

- EECS 542 "Computer Vision
- EECS 543 "Knowledge Based Systems"
- EECS 545 "Machine Learning"
- EECS 547 "Electronic Commerce"
- EECS 594 Introduction to Adaptive Systems"
- EECS 595 "Natural Language Processing"
- EECS 643 Theory of Neural Computation"
- EECS 644 Computational Modeling of Cognition"

Hardware Area Coursework Requirement:

Students must take two graduate hardware courses from the following list and get an A- or above in each. Students who get below an A- in a course may take another course from the list to satisfy the requirement.

- EECS 527 "Layout Synthesis and Optimization"
- EECS 570 "Parallel Computer Architecture"
- EECS 573 "Microarchitecture"
- EECS 577 "Reliable Computing Systems"
- EECS 578 "Computer-Aided Design and Verification of Digital Systems"
- EECS 579 "Digital System Testing"
- EECS 583 "Advanced Compilers"
- EECS 627 "VLSI Design II"

Software Area Coursework Requirement:

Students must take two graduate software courses from the following list and get an A- or above in each. Students who get below an A- in a course may take another course from the list to satisfy the requirement.

- EECS 571 "Principles of Real-Time Computing"

EECS 580 "Advanced Computer Graphics"
EECS 582 "Advanced Operating Systems"
EECS 583 "Advanced Compilers"
EECS 584 "Advanced Database Systems"
EECS 588 "Computer Network Security"
EECS 589 "Advanced Computer Networks"
EECS 590 "Graduate Programming Languages"
EECS 591 "Distributed Systems"

Theory Area Qualification Exam:

Students must take EECS 574 and 586, and get at least two A's or above in EECS 574, 575, and 586.

EECS 574 "Complexity Theory "
EECS 575 "Advanced Cryptography"
EECS 586 "Design and Analysis of Algorithms"

The VLSI and CAD Area Coursework Requirement:

Students must take two graduate VLSI and CAD courses from the following list and get an A- or above in each. Students who get below an A- in a course may take another course from the list to satisfy the requirement.

EECS 522 "Analog Integrated Circuits"
EECS 523 "Digital Integrated Circuit Technology"
EECS 527 "Layout Synthesis and Optimization"
EECS 578 "Computer-Aided Design and Verification of Digital Systems"
EECS 579 "Digital System Testing"
EECS 627 "VLSI Design II"

An exception may be made for students who have taken a course at another university that has been approved as equivalent to one in the above list. In such a case, the faculty who teach the course will give an oral exam to determine whether or not the student has knowledge equivalent to an A-. This oral exam will be administered at the same time as the other area qualifying exams. A typical oral exam will be administered by two faculty and last one hour.

4.3.3. Directed Study and Research Potential

A Ph.D. aspirant must demonstrate potential for conducting original research. This must be accomplished by either completing a research-oriented directed study course (599) for at least 3 credit hours, or a Master's Thesis for 6 credit hours; either must be completed (with a CSE Faculty member) in the EECS Department of The University of Michigan and may count toward the Master's degree. A formal written report is required with the directed study option. The faculty member supervising the directed study or Master's Thesis will provide a formal written evaluation.

4.3.4. Preliminary Examination

The Preliminary Examination (Prelim) is a major component of the Ph.D. qualification process. Each student will be given an oral examination on the student's directed study project and on material directly related to the student's research area. This prelim will last between one and two hours. This examination will be administered during the qualification examination period in mid-January, mid-May or mid-September. The examination will be given by three faculty members selected by the CSE Graduate Committee. None will be the director of the students' directed study

project. Examiners will be given the written report on the directed study at least one week before the examination, and each examiner will submit a written report on the examination. The student must submit four copies of the written report to the CSE Graduate Coordinator at least one week before the qualification exams begin.

4.4. Candidacy

The decision to admit a student to Candidacy is based on the following factors:

1. Successful completion of the CSE Qualification process.
2. Fulfillment of all other Rackham candidacy requirements such as residency requirements, cognate course work, and completion of CSE masters degree requirements for those without a relevant masters, etc..

A student may satisfy the Ph.D. cognate requirement (at least four (4) hours of graduate-level course work) by taking course(s) associated with another EECS program (not his/her own), by taking course(s) outside the department, or by a mixture thereof. Courses taken from other programs cannot overlap in content with computer related material. Any course in question must have prior approval of the CSE Graduate Committee.

To become a "Candidate", a student must satisfactorily complete all requirements listed above. In other words, the student must have been declared "qualified" by the CSE Program, and must have satisfied all of the CSE Program's and Rackham's candidacy requirements. Note that once all candidacy requirements are met, a student must apply for candidacy by submitting the appropriate forms via the CSE Graduate Office. These forms must be submitted during the term before you plan to become a candidate. Candidacy is not awarded automatically; it must be applied for.

The achievement of candidacy is considered an important milestone in a Ph.D. student's progress, and all students are expected to apply for candidacy as soon as they are eligible. A student with a relevant Master's degree is making satisfactory progress if candidacy is achieved within 3 full terms (1.5 years), and must be achieved within 4 full terms (2 years). Other students are making satisfactory progress if candidacy is achieved within 5 full terms (2.5 years), and must be achieved within 6 full terms (3 years). A student without adequate undergraduate coursework in CSE may petition for an extension to these deadlines; however, that petition must be made to the Graduate Committee before the end of the first term of study.

4.5. Dissertation

4.5.1. Dissertation Committee

Soon after admission into candidacy, the candidate and his or her advisor should form a Dissertation Committee and submit it to the CSE Graduate Committee for preliminary approval. You must request approval of the committee in writing listing the requested committee members form available on CSE Grad Web Site <http://www.eecs.umich.edu/eecs/graduate/cse/csegradpage.html>. This request form must be first approved by the students' chair (or co-chairs). Once approved by the CSE Graduate Committee, it will be forwarded to the Rackham Graduate School for their approval. Normally the advisor serves as chair or co-chair of this committee. It is the responsibility of the student and the advisor to find eligible faculty members willing to serve.

A typical CSE Dissertation Committee consists of three regular CSE Faculty and one cognate Rackham Faculty member representing a non-CSE discipline. The committee's composition must be approved by the CSE Graduate Program.

In addition to complying with all the Rackham requirements the CSE Graduate Program requires that: two (2) members of the committee must be tenure-track CSE faculty with at least a 75% appointment in CSE.

A CSE faculty member with a 0% appointment can serve as sole chair of a committee. A CSE faculty member with a 0% appointment can be a cognate member of a committee, however one person cannot be both a cognate and regular (non-cognate) member of the same committee. The Dissertation Committee is responsible for reviewing the student's progress, including the thesis proposal and the final dissertation. The dissertation committee must be approved at least one month before the thesis proposal date.

4.5.2. Thesis Proposal

After a student achieves candidacy, a thesis (dissertation) proposal must be successfully completed by a candidate within 7 full terms (3.5 years) from the start of graduate study to maintain satisfactory progress. A student with a relevant Master's degree must complete a thesis proposal within 5 full terms (2.5 years). The thesis proposal will be administered by the Dissertation Committee (see above). The student will submit a dissertation research proposal to the Dissertation Committee at least two weeks in advance of the date of an oral presentation. In the written proposal, the student must precisely identify the intellectual area in which he or she intends to pursue research and must demonstrate an in-depth understanding of that area. The student must give a general description of the research problem to be addressed and an outline of the approach that will be taken. It is desirable that the research problem be specified in considerable detail and that some initial results be presented. During the oral presentation, the student will present the proposed dissertation research, including relevant background material and preliminary research results. During and after the presentation, the Dissertation Committee will explore the research area with the student to determine whether the student has completed this phase successfully. The Dissertation Committee will prepare a written report on the outcome of the proposal presentation, and a copy of the written proposal will be placed in the student's file.

4.5.3. Dissertation and Final Defense

After the thesis proposal has been approved, the candidate can proceed with the thesis research and the writing of the dissertation. Upon completion, the dissertation must receive a written evaluation from each member of the Dissertation Committee and must be defended orally in an open examination (the Final Defense) before the Committee, in accordance with Rackham rules. (<http://www.rackham.umich.edu/OARD/>)

5. Ph.D. TRACK TIMETABLE

Students entering the Graduate Program with a **bachelor's degree** are required to meet the following deadlines:

1. **Qualification Deadline:** Complete the required courses from the four CSE areas as described above, pass the area qualifying examination, and pass the preliminary examination within 4 full terms from the date of admission. If the student starts in September, these requirements must be satisfied by mid-May of the second year. If the student starts in January, these requirements must be satisfied by mid-January two years after starting.

2. **Candidacy Deadline:** Achieve candidacy within 6 full terms (3 years from the date of admission). Achievement of candidacy within 5 full terms is required to maintain satisfactory progress.

3. **Thesis Proposal Deadline:** Meet the thesis proposal requirements within 3.5 years from the date of admission to maintain satisfactory progress.

4. **Ph.D. Completion Deadline:** Complete the dissertation within six years from the date of admission. Under normal conditions the dissertation should take an average of five years to complete.

Students entering the Graduate Program with a **relevant master's degree** are required to meet the following deadlines:

1. **Qualification Deadline:** Complete the required courses from the four CSE areas as described above, pass the area qualifying examination, and pass the preliminary examination within 3 full terms from the date of admission. If the student starts in September, these requirements must be satisfied by mid-January of the second year. If the student starts in January, these requirements must be satisfied by mid-May of the second year.

2. **Candidacy Deadline:** Achieve candidacy within 4 full terms (2 years from the date of admission). Achievement of candidacy within 3 full terms is required to maintain satisfactory progress.

3. **Thesis Proposal Deadline:** Pass the thesis proposal within 2.5 years from the date of admission to maintain satisfactory progress.

4. **Ph.D. Completion Deadline:** Complete the dissertation within five years from the date of admission.

A student who is unable to complete any of the degree requirements within the specified deadlines due to exceptional circumstances may petition the CSE Graduate Committee for a deadline extension.

CSE Ph.D. Deadlines

Entering with	Entry Date	Entry Date	Entry Date	Entry Date	Entry Date	Entry Date	Entry Date
Bachelors	Fall 2005	Fall 2006	Fall 2007	Fall 2008	Fall 2009	Fall 2010	Fall 2011
Quals	May 2007	May 2008	May 2009	May 2010	May 2011	May 2012	May 2013
Candidacy	March 2008	March 2009	March 2010	March 2011	March 2012	March 2013	March 2014
Thesis Prop.	December 2008	December 2009	December 2010	December 2011	December 2012	December 2013	December 2014
Completion	August 2011	August 2012	August 2013	August 2014	August 2015	August 2016	August 2017

Entering with	Entry Date	Entry Date	Entry Date	Entry Date	Entry Date	Entry Date	Entry Date
Masters	Fall 2005	Fall 2006	Fall 2007	Fall 2008	Fall 2009	Fall 2010	Fall 2011
Quals	January 2007	January 2008	January 2009	January 2010	January 2011	January 2012	January 2013
Candidacy	March 2007	March 2008	March 2009	March 2010	March 2011	March 2012	March 2013
Thesis Prop.	December 2007	December 2008	December 2009	December 2010	December 2011	December 2012	December 2013
Completion	August 2010	August 2011	August 2012	August 2013	August 2014	August 2015	August 2016

6. NON-DEGREE (NCFD) STUDENTS

The CSE Division will normally admit qualified students who are not candidates for a degree (NCFD students) to enable them to take graduate courses. Such students typically have a full-time job in a local industry or business in Southeastern Michigan and take relatively few courses. Students who are interested in a graduate degree program are strongly encouraged to apply as a regular graduate student, and not as an NCFD student. Note that courses taken by a student under NCFD status may *not* be subsequently used for a graduate degree. NCFD status is granted for one term at a time only.

7. POLICY FOR DROPPING COURSES

After the eighth week of a full term (fourth week of a half term), courses may be dropped or changed to Visit status only under exceptional circumstances and with the approval of the course instructor, advisor, and the graduate chair of the program. The specific deadline dates are posted in the CSE Graduate Office, 3909A CSE and on the CSE Program website. The Rackham Graduate School rules for dropping courses also apply (see the *Rackham Student Handbook* <http://www.rackham.umich.edu/OARD/>).

8. CSE COURSES

The following EECS graduate courses are associated with the CSE Graduate Program. Note that they may *not* be used as cognate courses by CSE students.

EECS 427. VLSI Design I	EECS 567 (MFG 567) (ME 567). Intro to Robotics
EECS 442. Computer Vision	EECS 568 Mobile Robotics: Methods and Algorithms
EECS 470. Computer Architecture	EECS 570. Parallel Computer Architecture
EECS 475. Introduction to Cryptography	EECS 571. Principles of Real-Time Computing
EECS 477. Introduction to Algorithms	EECS 573. Microarchitecture
EECS 478. Logic Circuit Synthesis and Optimization	EECS 574. Complexity Theory
EECS 480. Logic and Formal Verification	EECS 575. Advanced Cryptography.
EECS 481. Software Engineering	EECS 578. Computer-Aided Design Verification of Digital Systems
EECS 482. Introduction to Operating	EECS 579. Digital System Testing
EECS 483. Compiler Construction	EECS 580. Advanced Computer Graphics
EECS 484. Database Management Systems	EECS 581. Software Engineering Tools
EECS 485. Web Database and Information Systems	EECS 582. Advanced Operating Systems
EECS 487. Interactive Computer Graphics	EECS 583. Advanced Compilers
EECS 489. Computer Networks	EECS 584. Advanced Database Systems
EECS 490. Programming Languages	EECS 586. Design and Analysis of Algorithms
EECS 492. Introduction to Artificial Intelligence	EECS 587. Parallel Computing
EECS 493. User Interface Development	EECS 588. Computer and Network Security
EECS 494. Computer Game Design and Development	EECS 589. Advanced Computer Networks
EECS 527. Layout Synthesis and Optimization	EECS 590. Advanced Programming Languages
EECS 542. Vision Processing	EECS 591. Distributed Systems
EECS 543. Knowledge-Based Systems	EECS 592. Advanced Artificial Intelligence
EECS 545. Machine Learning	EECS 594. Introduction to Adaptive Systems
EECS 547 (SI 652). Electronic Commerce	EECS 595 (LING 541) (SI 661). Natural Language Processing
EECS 557. Communication	EECS 597 (SI 760) (LING 702). Language and

Information

EECS 598 Special Topics in EECS (approved on a case by case basis)

EECS 627. VLSI Design II

EECS 628. Advanced High Performance VLSI Design.

EECS 643 (PSYCH 643). Theory of Neural Computation

EECS 644 (PSYCH 644). Computational Modeling of Cognition

EECS 661 Discrete Event Systems

EECS 670. Special Topics in Computer Architecture

EECS 674. Special Topics in Theoretical Computer Science

EECS 682. Special Topics in Software Systems

EECS 684. Current Topics in Databases

EECS 691. Mobile Computing

EECS 692. Special Topics in Artificial Intelligence

EECS 695 (PSYCH 640). Neural Models and Psychological Processes

EECS 767 (SI 767). Advanced Natural Language Processing and Information Retrieval

EECS 770. Special Topics in Computer Systems

EECS 792 Advanced AI Techniques

EECS 892. Seminar in Artificial Intelligence

Note: Seminar and independent study course cannot be used toward the 500 level requirement

9. Electrical Engineering and Computer Science Courses

An up to date listing is at: <http://www.engin.umich.edu/students/bulletin/eecs/courses.html>

EECS 182 (SI 182). Building Applications for Information Systems *Prerequisite: none. I, II (4 credits)* Fundamental programming skills in the context of end-user software applications using a high-level language, such as Ruby or Python. Rapid design of a variety of information-oriented applications to gather, analyze, transform, manipulate, and publish data. Applications drawn from statistics, pattern matching, social computing, and computer games.

EECS 183. Elementary Programming Concepts *Prerequisite: none. (Credit for only one: EECS 183, ENGR 101) I, II (4 credits)* Fundamental concepts and skills of programming in a high-level language. Flow of control: selection, iteration, subprograms. Data structures: strings, arrays, records, lists, tables. Algorithms using selection and iteration (decision making, finding maxima/minima, searching, sorting, simulation, etc.) Good program design, structure and style are emphasized. Testing and debugging. Not intended for Engineering students (who should take ENGR 101), nor for CS majors in LSA who qualify to enter EECS 280.

EECS 203. Discrete Mathematics *Prerequisite: MATH 115. I, II (4 credits)* Introduction to the mathematical foundations of computer science. Topics covered include: propositional and predicate logic, set theory, function and relations, growth of functions and asymptotic notation, introduction to algorithms, elementary combinatorics and graph theory, and discrete probability theory.

EECS 215. Introduction to Electronic Circuits *Prerequisite: MATH 116, ENGR 101, Corequisite PHYSICS 240 (or 260). Cannot receive credit for both EECS 314 and EECS 215. I, II (4 credits)* Introduction to electronic circuits. Basic Concepts of voltage and current; Kirchhoff's voltage and current laws; Ohm's law; voltage and current sources; Thevenin and Norton equivalent circuits; DC and low frequency active circuits using operational amplifiers, diodes, and transistors; small signal analysis; energy and power. Time- and frequency-domain analysis of RLC circuits. Basic passive and active electronic filters. Laboratory experience with electrical signals and circuits.

EECS 216. Introduction to Signals and Systems *Prerequisite: EECS 215 or EECS 314 or BIOMEDE 211, preceded or accompanied by MATH 216. I, II (4 credits).* Theory and practice of signals and systems engineering in continuous and discrete time. Continuous-time linear time-invariant systems, impulse response, convolution. Fourier series, Fourier transforms, spectrum, frequency response and filtering. Sampling leading to basic digital signal processing using the discrete-time Fourier and the discrete Fourier transform. Laplace transforms, transfer functions, poles and zeros, stability. Applications of Laplace transform theory to RLC circuit analysis. Introduction to communications, control, and signal processing. Weekly recitations and hardware/Matlab software laboratories.

EECS 230. Electromagnetics I *Prerequisite: MATH 215, PHYS 240 (or 260), EECS 215. I, II (4 credits)* Vector

calculus. Electrostatics. Magnetostatics. Time-varying fields: Faraday's Law and displacement current. Maxwell's equations in differential form. Traveling waves and phasors. Uniform plane waves. Reflection and transmission at normal incidence. Transmission lines. Laboratory segment may include experiments with transmission lines, the use of computer-simulation exercises, and classroom demonstrations.

EECS 250 (NAVARCH 202). Electronic Sensing Systems *Prerequisite: preceded or accompanied by EECS 230 or PHYSICS 240. II (3 credits)* Introduction to properties and behavior of electromagnetic energy as it pertains to naval applications of communication, radar, and electro-optics. Additional topics include sound navigation and ranging (SONAR) tracking and guidance systems, and computer controlled systems. Several laboratory demonstrations will illustrate applications of the theories and concepts learned in the classroom.

EECS 270. Introduction to Logic Design *Prerequisite: EECS 183 or ENGR 101 or equivalent. I, II (4 credits)* Binary and non-binary systems, Boolean algebra, digital design techniques, logic gates, logic minimization, standard combinational circuits, sequential circuits, flip-flops, synthesis of synchronous sequential circuits, PLAs, ROMs, RAMs, arithmetic circuits, computer-aided design. Laboratory includes design and CAD experiments.

EECS 280. Programming and Introductory Data Structures *Prerequisite: MATH 115 and prior programming experience. I, II (4 credits)* Techniques and algorithm development and effective programming, top-down analysis, structured programming, testing, and program correctness. Program language syntax and static and runtime semantics. Scope, procedure instantiation, recursion, abstract data types, and parameter passing methods. Structured data types, pointers, linked data structures, stacks, queues, arrays, records, and trees.

EECS 281. Data Structures and Algorithms *Prerequisite: EECS 203 and EECS 280. I, II (4 credits)* Introduction to algorithm analysis and O-notation; Fundamental data structures including lists, stacks, queues, priority queues, hash tables, binary trees, search trees, balanced trees and graphs; searching and sorting algorithms; recursive algorithms; basic graph algorithms; introduction to greedy algorithms and divide and conquer strategy. Several programming assignments.

EECS 282. Information Systems Design and Programming *Prerequisite: EECS 182 or EECS 183 or ENGR 101 AND Math 115. II (4 credits)* Techniques for algorithm development and programming. Learning a programming language, such as Java, which is suitable for designing enterprise-scale information systems; data structures including stacks, queues, trees, and dictionaries; recursion; program complexity; object-oriented design; handling exceptions, debugging, and testing; introduction to database design with JDBC and SQL.

EECS 283. Programming for Science and Engineering *Prerequisite: EECS 183 or ENGR 101 or equivalent. As needed (4 credits)* Programming concepts with numeric applications for mathematics, the sciences, and engineering. Object-oriented programming, abstract data types, and standard class libraries with numeric and non-numeric applications. Elementary data structures, linked lists, and dynamic allocation. Searching and sorting methods. Not intended for CS majors.

EECS 285. A Programming Language or Computer System *Prerequisite: some programming experience. I (2*

credits) A course covering a complex computer system or programming language. Programming problems will be assigned. Specific languages or systems to be offered will be announced in advance.

EECS 311. Electronic Circuits *Prerequisite: EECS 216 or (EECS 206 and EECS 215). I, II (4 credits)* Circuit models for bipolar junction and field-effect transistors; nonlinear elements; small-signal and piecewise analysis of nonlinear circuits; analysis and design of basic single-stage transistor amplifiers: gain, biasing, and frequency response; digital logic circuits; memory circuits (RAM, ROM). Design projects. Lecture and laboratory.

EECS 312. Digital Integrated Circuits *Prerequisite: EECS 216 or (EECS 206 and EECS 215). I, II (4 credits)* Design and analysis of static CMOS inverters and complex combinational logic gates. Dynamic logic families, pass-transistor logic, ratioed logic families. Sequential elements (latches, flip-flops). Bipolar-based logic; ECL, BiCMOS. Memories; SRAM, DRAM, EEPROM, PLA. I/O circuits and interconnect effects. Design project(s). Lecture, recitation and software labs.

EECS 314. Electrical Circuits, Systems, and Applications *Prerequisite: MATH 214 or MATH 216, PHYSICS 240. Credit for only one: EECS 215, or EECS 314. Not open to CE or EE students. I, II (4 credits)* Students will learn about electrical systems operation, specifications and interactions with other modules. Theory will be motivated by the use of examples taken from a variety of fields. Topics covered include circuit fundamentals, frequency response and transients, analog and digital electronics. In lab, students will build and analyze circuits including amplifiers, filters and temperature controllers.

EECS 320. Introduction to Semiconductor Devices *Prerequisite: EECS 215 and PHYSICS 240 or 260. I, II (4 credits)* Introduction to semiconductors in terms of atomic bonding and electron energy bands. Equilibrium statistics of electrons and holes. Carrier dynamics; continuity, drift, and diffusion currents; generation and recombination processes, including important optical processes. Introduction to: PN junctions, metal-semiconductor junctions, light detectors and emitters; bipolar junction transistors, junction and MOSFETs.

EECS 330. Electromagnetics II *Prerequisite: EECS 230. I, II (4 credits)* Time-varying electromagnetic fields and Maxwell's equations. Plane-wave propagation, reflection, and transmission. Geometric optics. Radiation and antennas. System applications of electromagnetic waves. Laboratory segment consists of experiments involving microwave and optical measurements and the design of practical systems.

EECS 334. Principles of Optics *Prerequisite: PHYSICS 240. A student can receive credit for only one: EECS 334 or PHYSICS 402. II (4 credits)* Basic principles of optics: light sources and propagation of light; geometrical optics, lenses and imaging; ray tracing and lens aberrations; interference of light waves, coherent and incoherent light beams; Fresnel and Fraunhofer diffraction. Overview of modern optics with laboratory demonstrations.

EECS 353. Introduction to Communications Systems *Prerequisite: EECS 216 or EECS 306. II (4 credits)* Mathematical analysis of signals and signal processing used in analog and digital communication systems; sampling; quantization; pulse transmission; intersymbol interference; Nyquist criterion; partial response signals; eye diagrams;

equalization; mixing; analog modulation and demodulation; receiver architectures; phase-locked loops; signal-to-noise ratio analysis; digital modulation and demodulation; spread spectrum communications.

EECS 370. Introduction to Computer Organization *Prerequisite: (EECS 203 or EECS 270) and (EECS 280 or EECS 283). I, II (4 credits)* Basic concepts of computer organization and hardware. Instructions executed by a processor and how to use these instructions in simple assembly-language programs. Stored-program concept. Datapath and control for multiple implementations of a processor. Performance evaluation, pipelining, caches, virtual memory, input/output.

EECS 373. Design of Microprocessor Based Systems *Prerequisite: EECS 270 and EECS 370 and junior standing. I, II (4 credits)* Principles of hardware and software microcomputer interfacing; digital logic design and implementation. Experiments with specially designed laboratory facilities. Introduction to digital development equipment and logic analyzers. Assembly language programming. Lecture and laboratory.

EECS 376. Foundations of Computer Science *Prerequisite: EECS 203 and EECS 280 or equivalent. I, II (4 credits)* An introduction to computation theory: finite automata, regular languages, pushdown automata, context-free languages, Turing machines, recursive languages and functions, and computational complexity.

EECS 381. Object Oriented and Advanced Programming *Prerequisite: EECS 281. I, II (4 credits)* Programming techniques in Standard C++ for large-scale, complex, or high-performance software. Encapsulation, automatic memory management, exceptions, generic programming with templates and function objects, Standard Library algorithms and containers. Using single and multiple inheritance and polymorphism for code reuse and extensibility; basic design idioms, patterns, and notation.

EECS 382. Internet-scale Computing *Prerequisite: EECS 281 or EECS 282. I (4 credits)* Systems-level programming techniques and concepts for the design of software systems: computer memory model; pointer safety; concurrent programming using threads; coding vulnerabilities and secure coding; network programming and remote procedure calls; reading/writing objects to disk; client-server and distributed systems. No C++ background assumed. Programming labs in C++.

EECS 398. Special Topics *Prerequisite: permission of instructor. (1-4 credits)* Topics of current interest selected by the faculty. Lecture, seminar, or laboratory.

EECS 399. Directed Study *Prerequisite: Sophomore or Junior Standing, and Permission of Instructor. (1-4 credits)* Provides an opportunity for undergraduate students to work on research problems in EECS or areas of special interest such as design problems. For each hour of credit, it is expected that the student will work an average of three or four hours per week. Oral presentation and/or written report due at end of term.

EECS 401. Probabilistic Methods in Engineering *Prerequisite: EECS 216 or EECS 306 or graduate standing. I, II (4 credits)* Basic concepts of probability theory. Random variables: discrete, continuous, and conditional probability distributions; averages; independence. Statistical inference: hypothesis testing and estimation. Introduction to discrete and continuous random processes.

EECS 402. Computer Programming For Scientists and Engineers *Prerequisite: Senior or graduate standing (3 credits)* Presents concepts and hands-on experience for designing and writing programs using one or more programming languages currently important in solving real-world problems. Intended for senior undergraduates and graduate students in science or engineering fields. Not available for credit to EECS majors; will not substitute for Eng. 101.

EECS 406 (ENGR 406). High-Tech Entrepreneurship *Prerequisite: none. I (4 credits)* Four aspects of starting high-tech companies are discussed: opportunity and strategy, creating new ventures, functional development, and growth and financing. Also, student groups work on reviewing business books, case studies, elevator and investor pitches. Different financing models are covered, including angel or VC funding and small business (SBIR) funding.

EECS 410 (ENGR 410) Patent Fundamentals for Engineers *Prerequisite: (junior or senior Standing) or graduate standing. I Alternate years. (4 credits)* This course covers the fundamentals of patents for engineers. The first part of the course focuses on the rules and codes that govern patent prosecution, and the second part focuses on claim drafting and amendment writing. Other topics covered include litigation, ethics and licensing.

EECS 411. Microwave Circuits I *Prerequisite: EECS 311 or 330, or graduate standing. I (4 credits)* Transmission-line theory, microstrip and coplanar lines, S-parameters, signal-flow graphs, matching networks, directional couplers, low-pass and band-pass filters, diode detectors. Design, fabrication, and measurements (1-10GHz) of microwave-integrated circuits using CAD tools and network analyzers.

EECS 413. Monolithic Amplifier Circuits *Prerequisite: EECS 311 and EECS 320 or graduate standing. I (4 credits)* Analysis and design of BJT and MOS multi-transistor amplifiers. Feedback theory and application to feedback amplifiers. Stability considerations, pole-zero cancellation, root locus techniques in feedback amplifiers. Detailed analysis and design of BJT and MOS integrated operational amplifiers. Lectures and laboratory.

EECS 414. Introduction to MEMS *Prerequisite: MATH 215 and MATH 216 and PHYSICS 240 or graduate standing I (4 credits)* Micro electro mechanical systems (MEMS), devices, and technologies. Micro-machining and microfabrication techniques, including planar thin-film processing, silicon etching, wafer bonding, photolithography, deposition, and etching. Transduction mechanisms and modeling in different energy domains. Analysis of micromachined capacitive, piezoresistive, and thermal sensors/actuators and applications. Computer-aided design for MEMS layout, fabrication, and analysis.

EECS 417 (BIOMEDE 417). Electrical Biophysics *Prerequisite: EECS 206 and 215 or graduate standing. II (4 credits)* Electrical biophysics of nerve and muscle; electrical conduction in excitable tissue; quantitative models for nerve and muscle, including the Hodgkin Huxley equations; biopotential mapping, cardiac electrophysiology, and functional electrical stimulation; group projects. Lecture and recitation.

EECS 420. Physical Principles Underlying Smart Devices *Prerequisite: (EECS 320 and EECS 330) or graduate standing. I (4 credits)* Structural properties of materials. Basic quantum mechanics of electrons in solids. Band theory and trap states. Charge transport, band conduction and hopping conduction. Optical properties of materials. Piezoelectric

and ferro-electric phenomena. Magnetic effects in materials. Physical phenomena will be related transistors, light emitters, sensor and memory devices.

EECS 421. Properties of Transistors *Prerequisite: EECS 320 or graduate standing. I (4 credits)* In depth understanding of the device physics and working principle of some basic IC components: metal-semiconductor junctions, P-N junctions, metal-oxide-semiconductor junctions, MOSFETs and BJTs

EECS 423. Solid-State Device Laboratory *Prerequisite: EECS 320 or graduate standing. I (4 credits)* Semiconductor material and device fabrication and evaluation: diodes, bipolar and field-effect transistors, passive components. Semiconductor processing techniques: oxidation, diffusion, deposition, etching, photolithography. Lecture and laboratory. Projects to design and simulate device fabrication sequence.

EECS 425. Integrated Microsystems Laboratory *Prerequisite: EECS 311 or EECS 312 or EECS 414 or graduate standing. II (4 credits)* Development of a complete integrated microsystem, from functional definition to final test. MEMS-based transducer design and electrical, mechanical and thermal limits. Design of MOS interface circuits. MEMS and MOS chip fabrication. Mask making, pattern transfer, oxidation, ion implantation and metallization. Packaging and testing challenges. Students work in interdisciplinary teams.

EECS 427. VLSI Design I *Prerequisite: (EECS 270 and EECS 312 and EECS 320) or graduate standing. I, II (4 credits)* Design techniques for rapid implementations of very large-scale integrated (VLSI) circuits, MOS technology and logic. Structured design. Design rules, layout procedures. Design aids: layout, design rule checking, logic, and circuit simulation. Timing. Testability. Architectures for VLSI. Projects to develop and lay out circuits.

EECS 429. Semiconductor Optoelectronic Devices *Prerequisite: EECS 320 or graduate standing. II (4 credits)* Materials for optoelectronics, optical processes in semiconductors, absorption and radiation, transition rates and carrier lifetime. Principles of LEDs, lasers, photodetectors, modulators and solar cells. Optoelectronic integrated circuits. Designs, demonstrations and projects related to optoelectronic device phenomena.

EECS 430 (AOSS 431). Radiowave Propagation and Link Design *Prerequisite: EECS 330. II (4 credits)* Fundamentals of electromagnetic propagation and radiation; radiowave propagation in different environments (near Earth, troposphere, ionosphere, indoor and urban); antenna parameters; practical antennas; link analysis; system noise; fading and multipath interference. Course includes lectures, labs and a project in which student teams develop and implement practical wireless systems.

EECS 434. Principles of Photonics *Prerequisite: EECS 330 or EECS 334 or permission of instructor or graduate standing. I (4 credits)* Introduction to photonics, opto-electronics, lasers and fiber-optics. Topics include mirrors, interferometers, modulators and propagation in waveguides and fibers. The second half treats photons in semiconductors, including semi-conductor lasers, detectors and noise effects. System applications include fiber lightwave systems, ultra-high-peak power lasers, and display technologies.

EECS 435. Fourier Optics *Prerequisite: (EECS 306 or EECS 216), preceded or accompanied by EECS 334 and junior standing or graduate standing. II odd years. (3 credits)* Basic physical optics treated from the viewpoint of Fourier analysis. Fourier-transform relations in optical systems. Theory of image formation and Fourier transformation by lenses. Frequency response of diffraction-limited and aberrated imaging systems. Coherent and incoherent light. Comparison of imagery with coherent and with incoherent light. Resolution limitations. Optical information processing, including spatial matched filtering.

EECS 438. Advanced Lasers and Optics Laboratory *Prerequisite: EECS 334 or EECS 434 or graduate standing. II (4 credits)* Construction and design of lasers; gaussian beams; nonlinear optics; fiber optics; detectors; dispersion; Fourier optics; spectroscopy. Project requires the design and set-up of a practical optical system.

EECS 442. Computer Vision *Prerequisite: EECS 281 or graduate standing. Alternate years (4 credits)* Computational methods for the recovery, representation, and application of visual information. Topics from image formation, binary images, digital geometry, similarity and dissimilarity detection, matching, curve and surface fitting, constraint propagation relaxation labeling, stereo, shading texture, object representation and recognition, dynamic scene analysis, and knowledge based techniques. Hardware, software techniques.

EECS 451. Digital Signal Processing and Analysis *Prerequisite: EECS 216 or EECS 306 or graduate standing. I, II (4 credits)* Introduction to digital signal processing of continuous and discrete signals. The family of Fourier Transforms including the Discrete Fourier Transform (DFT). Development of the Fast Fourier Transform (FFT). Signal sampling and reconstruction. Design and analysis of digital filters. Correlation and spectral estimation.

EECS 452. Digital Signal Processing Design Laboratory *Prerequisite: EECS 280, and (EECS 451 or EECS 455) or graduate standing. I, II (4 credits)* Architectures of single-chip DSP processors. Laboratory exercises using two state-of-the-art fixed-point processors; A/D and D/A conversion, digital wave-form generators, and real-time FIR and IIR filters. Central to this course is a team project in real-time DSP design (including software and hardware).

EECS 455. Digital Communication Signals and Systems *Prerequisite: (EECS 216 or EECS 306, and EECS 401) or graduate standing I (4 credits)* Digital transmission techniques in data communications, with application to computer and space communications; design and detection of digital signals for low error rate; forward and feedback transmission techniques; matched filters; modems, block and convolutional coding; Viterbi decoding. Discussion on Discrete-time LTI systems, Discrete-time Fourier Transforms (DTFT) along with homework problems.

EECS 458 (BIOMEDE 458). Biomedical Instrumentation and Design *Prerequisite: EECS 215 or EECS 314 or consent of instructor or graduate standing. I, II (4 credits)* Measurement and analysis of biopotentials and biomedical transducer characteristics; electrical safety; applications of FETs, integrated circuits, operational amplifiers for signal processing and computer interfacing; signal analysis and display on the laboratory minicomputer. Lectures and laboratory.

EECS 460. Control Systems Analysis and Design *Prerequisite: EECS 216 or EECS 306 or graduate standing. I (4*

credits) Basic techniques for analysis and design of controllers applicable in any industry (e.g. automotive, aerospace, computer, communication, chemical, bioengineering, power, etc.) are discussed. Both time- and frequency-domain methods are covered. Root locus, Nyquist and Bode plot-based techniques are outlined. Computer-based experiment and discussion sessions are included in the course.

EECS 461. Embedded Control Systems *Prerequisite: EECS 216 or EECS 306 or EECS 373 or graduate standing. I (4 credits)* Basic interdisciplinary concepts needed to implement a microprocessor based control system. Sensors and actuators. Quadrature decoding. Pulse width modulation. DC motors. Force feedback algorithms for human computer interaction. Real time operating systems. Networking. Use of MATLAB to model hybrid dynamical systems. Autocode generation for rapid prototyping. Lecture and laboratory.

EECS 470. Computer Architecture *Prerequisite: (EECS 370 and EECS 270) or graduate standing. I, II (4 credits)* Basic concepts of computer architecture and organization. Computer evolution. Design methodology. Performance evaluation. Elementary queuing models. CPU architecture instruction sets. ALU design. Hardware and micro-programmed control. Nanoprogramming. Memory hierarchies. Virtual memory. Cache design. Input-output architectures. Interrupts and DMA. I/O processors. Parallel processing. Pipelined processors. Multiprocessors.

EECS 475. Introduction to Cryptography *Prerequisite: (EECS 203 or MATH 312 or MATH 412) and (EECS 183 or EECS 280). I, alternating years (4 credits)* Covers fundamental concepts, algorithms, and protocols in cryptography. Topics: ancient ciphers, Shannon theory, symmetric encryption, public key encryption, hash functions, digital signatures, key distribution. Highlights AES, RSA, discrete log, elliptic curves. Emphasizes rigorous mathematical study in terms of algorithmic complexity. Includes necessary background from algorithms, probability, number theory, and algebra.

EECS 477. Introduction to Algorithms *Prerequisite: EECS 281 or graduate standing. II (4 credits)* Fundamental techniques for designing efficient algorithms and basic mathematical methods for analyzing their performance. Paradigms for algorithm design: divide-and-conquer, greedy methods, graph search techniques, dynamic programming. Design of efficient data structures and analysis of the running time and space requirements of algorithms in the worst and average cases.

EECS 478. Logic Circuit Synthesis and Optimization *Prerequisite: (EECS 203, EECS 270, and senior standing) or graduate standing. I, II (4 credits)* Advanced design of logic circuits. Technology constraints. Theoretical foundations. Computer-aided design algorithms. Two-level and multilevel optimization of combinational circuits. Optimization of finite-state machines. High-level synthesis techniques: modeling, scheduling, and binding. Verification and testing.

EECS 480. Logic and Formal Verification *Prerequisite: EECS 281 and (EECS 376 or EECS 270). I, alternating years (4 credits)* An introduction to current methodologies for verifying computer systems. Topics covered include logic and theorem proving; transition systems; temporal logic and the mu-calculus; modeling sequential and concurrent systems; model checking methods; binary decision diagrams; and controlling state explosion. Students will complete a project using current model checking technology.

EECS 481. Software Engineering *Prerequisite: EECS 281 or graduate standing. I (4 credits)* Pragmatic aspects of the production of software systems, dealing with structuring principles, design methodologies and informal analysis. Emphasis is given to development of large, complex software systems. A term project is usually required.

EECS 482. Introduction to Operating Systems *Prerequisite: (EECS 281 and EECS 370) or graduate standing. I, II (4 credits)* Operating system design and implementation: multi-tasking; concurrency and synchronization; inter-process communication; deadlock; scheduling; resource allocation; memory and storage management; input-output; file systems; protection and security. Students write several substantial programs dealing with concurrency and synchronization in a multi-task environment, with file systems, and with memory management.

EECS 483. Compiler Construction *Prerequisite: EECS 281 or graduate standing. II (4 credits)* Introduction to compiling techniques including parsing algorithms, semantic processing and optimization. Students implement a compiler for a substantial programming language using a compiler generating system.

EECS 484. Database Management Systems *Prerequisite: EECS 281 or graduate standing. I, II (4 credits)* Concepts and methods for the design, creation, query and management of large enterprise databases. Functions and characteristics of the leading database management systems. Query languages such as SQL, forms, embedded SQL, and application development tools. Database design, integrity, normalization, access methods, query optimization, transaction management and concurrency control and recovery.

EECS 485. Web Database and Information Systems *Prerequisites: {EECS major OR Informatics major AND (EECS 281 OR EECS 382)} OR graduate standing. II (4 credits)* Concepts surrounding Web information systems, including client/server systems, security, XML, information retrieval and search engines, and data replication issues. Includes substantial final project involving development of a database-backed web site.

EECS 487. Interactive Computer Graphics *Prerequisite: EECS 281 or graduate standing. II (4 credits)* Computer graphics hardware, line drawing, rasterization, anti-aliasing, graphical user interface (GUI), affine geometry, projective geometry, geometric transformation, polygons, curves, splines, solid models, lighting and shading, image rendering, ray tracing, radiosity, hidden surface removal, texture mapping, animation, virtual reality, and scientific visualization.

EECS 489. Computer Networks *Prerequisite: EECS 482 or graduate standing. II (4 credits)* Protocols and architectures of computer networks. Topics include client-server computing, socket programming, naming and addressing, media access protocols, routing and transport protocols, flow and congestion control, and other application-specific protocols. Emphasis is placed on understanding protocol design principles. Programming problems to explore design choices and actual implementation issues assigned.

EECS 490. Programming Languages *Prerequisite: EECS 281. II (4 credits)* Fundamental concepts in programming languages. Course covers different programming languages including functional, imperative, object-oriented, and logic programming languages; different programming language features for naming, control flow, memory management, concurrency, and modularity; as well as methodologies, techniques, and tools for writing correct and maintainable

programs.

EECS 492. Introduction to Artificial Intelligence *Prerequisite: EECS 281 or graduate standing. I, II (4 credits)*

Fundamental concepts of AI, organized around the task of building computational agents. Core topics include search, logic, representation and reasoning, automated planning, decision making under uncertainty, and machine learning.

EECS 493. User Interface Development *Prerequisite: EECS 281 or graduate standing. II (4 credits)*

Concepts and techniques for designing computer system user interfaces to be easy to learn and use, with an introduction to their implementation. Task analysis, design of functionality, display and interaction design, and usability evaluation. Interface programming using an object-oriented application framework. Fluency in a standard object-oriented programming language is assumed.

EECS 494. Computer Game Design and Development *Prerequisite: EECS 281 or graduate standing. I (4 credits)*

Concepts and methods for the design and development of computer games. Topics include: history of games, 2D graphics and animation, sprites, 3D animation, binary space partition trees, software engineering, game design, interactive fiction, user interfaces, artificial intelligence, game SDK's, networking, multi-player games, game development environments, commercialization of software.

EECS 496. Major Design Experience Professionalism *Prerequisite: senior standing. I, II (2 credits)*

Design principles for multidisciplinary team projects, team strategies, entrepreneurial skills, ethics, social and environmental awareness, and life long learning. Each student *must* take (simultaneously) Tech Comm 496 (2 cr.) and one of the approved 400-level team project courses in computing (4 cr.).

EECS 497. EECS Major Design Projects *Prerequisite: Senior standing, EECS 281, EECS 370, Tech Comm 300, and at least four credit hours of Upper Level Electives in either Computer Science or Computer Engineering. I, II (4 credits)*

Professional problem-solving methods developed through intensive group studies. Normally one significant design project is chosen for entire class requiring multiple EECS disciplines and teams. Use of analytic, computer, design, and experimental techniques where applicable are used. Projects are often interdisciplinary allowing non-EECS seniors to also take the course (consult with instructor).

EECS 498. Special Topics *Prerequisite: permission of instructor. (1-4 credits)* Topics of current interest selected by the faculty. Lecture, seminar or laboratory.

EECS 499. Directed Study *Prerequisite: senior standing in EECS. I, II, III (1-4 credits)*

Provides an opportunity for undergraduate students to work in on substantial research problems in EECS or areas of special interest such as design problems. For each hour of credit, it is expected that the student will work an average of three or four hours per week and that the challenges will be comparable with other 400 level EECS classes. Oral presentation and/or written report due at end of term. Not open to graduate students.

EECS 500. Tutorial Lecture Series in System Science *Prerequisite: graduate standing; mandatory satisfactory/*

unsatisfactory. I, II (1 credit) Students are introduced to the frontiers of System Science research. Sections 01, 02, and 03 are devoted, respectively, to Communications, Control, and Signal Processing. The tutorials are delivered by leaders of the respective research fields, invited from academia and industry. The presentations are self-contained and accessible to all graduate students in System Science.

EECS 501. Probability and Random Processes *Prerequisite: EECS 401 or graduate standing. I, II (4 credits)*

Introduction to probability and random processes. Topics include probability axioms, sigma algebras, random vectors, expectation, probability distributions and densities, Poisson and Wiener processes, stationary processes, autocorrelation, spectral density, effects of filtering, linear least-squares estimation, and convergence of random sequences.

EECS 502. Stochastic Processes *Prerequisite: EECS 501. II Alternate years (3 credits)* Correlations and spectra.

Quadratic mean calculus, including stochastic integrals and representations, wide-sense stationary processes (filtering, white noise, sampling, time averages, moving averages, autoregression). Renewal and regenerative processes, Markov chains, random walk and run, branching processes, Markov jump processes, uniformization, reversibility, and queuing applications.

EECS 503. Introduction to Numerical Electromagnetics *Prerequisite: EECS 330. I (3 credits)* Introduction to

numerical methods in electromagnetics including finite difference, finite element and integral equation methods for static, harmonic and time dependent fields; use of commercial software for analysis and design purposes; applications to open and shielded transmission lines, antennas, cavity resonances and scattering.

EECS 509. BioMEMS *Prerequisite: none. II Alternate years (3 credits)* Latest advances in bioMEMS, specifically

microsystems targeting developmental biology and cell culture. Organism's development, from genome to multicellular tissue. BioMEMS devices: microPCR chips, microfluidic mixers, tissue scaffolds. Familiarize students with microfabrication and microsystems. View and evaluate bioMEMS devices and innovations. Implantable and diagnostic microsystems. Critical evaluation of publications required. A principal component of the grade will be a written NSF or NIH exploratory proposal.

EECS 511. Integrated Analog/Digital Interface Circuits *Prerequisite: EECS 413 or permission of instructor. II (4*

credits) This course covers most of the well known analog to digital conversion schemes. These include the flash, folding, multi-step and pipeline Nyquist rate, architectures. Oversampling converters are also discussed. Practical design work is a significant part of this course. Students design and model complete converters.

EECS 512. Amorphous and Microcrystalline Semiconductor Thin Film Devices *Prerequisite: EECS 421 and/or permission of instructor. I (3 credits)* Introduction and fundamentals of physical, optical and electrical properties of

amorphous and microcrystalline semiconductor based devices: MIM structures, Schottky diodes, p-i-n junctions, heterojunctions, MIS structures, thin-film transistors, solar cells, threshold and memory switching devices and large area x-ray radiation detectors.

EECS 513. Flat Panel Displays *Prerequisite: EECS 423, EECS 512 and/or permission of instructor. II (3 credits)*

Introduction and fundamentals to the passive, active, reflective and emissive flat panel display technologies. This course will discuss the physics, operating principles, properties and technology of the flat panel displays.

EECS 514. Advanced MEMS Devices and Technologies *Prerequisite: EECS 414. II (4 credits)* Advanced micro electro mechanical systems (MEMS) devices and technologies. Transduction techniques, including piezoelectric, electrothermal, and resonant techniques. Chemical, gas, and biological sensors, microfluidic and biomedical devices. Micromachining technologies such as laser machining and microdrilling, EDM, materials such as SiC and diamond. Sensor and actuator analysis and design through CAD.

EECS 515. Integrated Microsystems *Prerequisite: EECS 414. I (4 credits)* Review of interface electronics for sense and drive and their influence on device performance, interface standards, MEMS and circuit noise sources, packaging and assembly techniques, testing and calibration approaches, and communication in integrated microsystems. Applications, including RF MEMS, optical MEMS, bioMEMS, and microfluidics. Design project using CAD and report preparation.

EECS 516 (BIOMEDE 516). Medical Imaging Systems *Prerequisite: EECS 451. I (3 credits)* Principles of modern medical imaging systems. For each modality the basic physics is described, leading to a systems model of the imager. Fundamental similarities between the imaging equations of different modalities will be stressed. Modalities covered include radiography, x-ray computed tomography (CT), NMR imaging (MRI) and real-time ultra-sound.

EECS 517 (NERS 578). Physical Processes in Plasmas *Prerequisite: EECS 330. II, even years (3 credits)* Plasma physics applied to electrical gas discharges used for material processing. Gas kinetics; atomic collisions; transport coefficients; drift and diffusion; sheaths; Boltzmann distribution function calculation; plasma simulation; plasma diagnostics by particle probes, spectroscopy, and electromagnetic waves; analysis of commonly used plasma tools for materials processing.

EECS 518 (AOSS 595). Magnetosphere and Solar Wind *Prerequisite: graduate standing. I, even years (3 credits)* General principles of magnetohydrodynamics; theory of the expanding atmospheres; properties of solar wind, interaction of solar wind with the magneto-sphere of the Earth and other planets; bow shock and magnetotail, trapped particles, auroras.

EECS 519 (NERS 575). Plasma Generation and Diagnostics Laboratory *Prerequisite: preceded or accompanied by a course covering electromagnetism. II (4 credits)* Laboratory techniques for plasma ionization and diagnosis relevant to plasma processing, propulsion, vacuum electronics, and fusion. Plasma generation includes: high voltage-DC, radio frequency, and electron beam sustained discharges. Diagnostics include: Langmuir probes, microwave cavity perturbation, microwave interferometry, laser schlieren, and optical emission spectroscopy. Plasma parameters measured are: electron/ion density and electron temperature.

EECS 520. Electronic and Optical Properties of Semiconductors *Prerequisite: EECS 420 or EECS 540. II (4 credits)* The course discusses in detail the theory behind important semiconductor-based experiments such as Hall effect and Hall

mobility measurement; velocity-field measurement; photoluminescence; gain; pump-probe studies; pressure and strain-dependent studies. Theory will cover: Bandstructure in quantum wells; effect of strain on bandstructure; transport theory; Monte Carlo methods for high field transport; excitons, optical absorption, luminescence and gain.

EECS 521. High-Speed Transistors *Prerequisite: EECS 421. II (3 credits)* Detailed theory of high-speed digital and high-frequency analog transistors. Carrier injection and control mechanisms. Limits to miniaturization of conventional transistor concepts. Novel submicron transistors including MESFET, heterojunction and quasi-ballistic transistor concepts.

EECS 522. Analog Integrated Circuits *Prerequisite: EECS 413. II (4 credits)* Review of integrated circuit fabrication technologies and BJT and MOS transistor models. Detailed analysis and design of analog integrated circuits, including power amplifiers, voltage references, voltage regulators, rectifiers, oscillators, multipliers, mixers, phase detectors, and phase-locked loops. Design projects. Lectures and discussion.

EECS 523. Digital Integrated Technology *Prerequisite: (EECS 423 or EECS 425) and EECS 311 and EECS 320. I (4 credits)* Integrated circuit fabrication overview, relationships between processing choices and device performance characteristics. Long-channel device I-V review, short-channel MOSFET I-V characteristics including velocity saturation, mobility degradation, hot carriers, gate depletion. MOS device scaling strategies, silicon-on-insulator, lightly-doped drain structures, on-chip interconnect parasitics and performance. Major CMOS scaling challenges. Process and circuit simulation.

EECS 525. Advanced Solid State Microwave Circuits *Prerequisite: EECS 411 and (EECS 421 or EECS 521). I (3 credits)* General properties and design of linear and nonlinear solid state microwave circuits including: amplifier gain blocks, low-noise, broadband and power amplifiers, oscillators, mixer and multiplier circuits, packaging, system implementation for wireless communication.

EECS 527. Layout Synthesis and Optimization *Prerequisite: EECS 281 or EECS 478 or graduate standing. Every third term, I or II (3 or 4 credits)* Theory of circuit partitioning, floorplanning and placement algorithms. Techniques for routing and clock tree design. Timing analysis and cycle time optimization. Topics in low-power design. Large-scale optimization heuristics, simulated annealing and AI techniques in CAD. Modern physical design methodologies and CAD software development.

EECS 528. Principles of Microelectronics Process Technology *Prerequisite: EECS 421 and EECS 423. II (3 credits)* Theoretical analysis of the chemistry and physics of process technologies used in micro-electronics fabrication. Topics include: semiconductor growth, material characterization, lithography tools, photo-resist models, thin film deposition, chemical etching, plasma etching, electrical contact formation, micro-structure processing, and process modeling.

EECS 529. Semiconductor Lasers and LEDs *Prerequisite: EECS 429. I (3 credits)* Optical processes in semiconductors, spontaneous emission, absorption gain, stimulated emission. Principles of light-emitting diodes, including transient effects, spectral and spatial radiation fields. Principles of semiconducting lasers; gain-current

relationships, radiation fields, optical confinement and transient effects.

EECS 530 (APPPHYS 530). Electromagnetic Theory I *Prerequisite: EECS 330 or Physics 438. I (3 credits)*

Maxwell's equations, constitutive relations and boundary conditions. Potentials and the representation of electromagnetic fields. Uniqueness, duality, equivalence, reciprocity and Babinet's theorems. Plane, cylindrical, and spherical waves. Waveguides and elementary antennas. The limiting case of electro- and magneto-statics.

EECS 531. Antenna Theory and Design *Prerequisite: EECS 330. II (3 credits)* Theory of transmitting and receiving antennas. Reciprocity. Wire antennas: dipoles, loops and traveling-wave antennas. Analysis and synthesis of linear arrays. Phased arrays. Input impedance and method of moments. Mutual impedance. Aperture antennas: slot, Babinet's principle. Microstrip antennas. Horns, reflector and lens antennas.

EECS 532 (AOSS 587). Microwave Remote Sensing I: Radiometry *Prerequisite: EECS 330, graduate standing. I odd years (3 credits)* Radiative transfer theory: blackbody radiation; microwave radiometry; atmospheric propagation and emission; radiometer receivers; surface and volume scattering and emission; applications to meteorology, oceanography, and hydrology.

EECS 533. Microwave Measurements Laboratory *Prerequisite: EECS 330, Graduate Standing. II (3 credits)*

Advanced topics in microwave measurements: power spectrum and noise measurement, introduction to state-of-the-art microwave test equipment, methods for measuring the dielectric constant of materials, polarimetric radar cross section measurements, near field antenna pattern measurements, electromagnetic emission measurement (EM compatibility). Followed by a project that will include design, analysis, and construction of a microwave subsystem.

EECS 534. Design and Characterization of Microwave Devices and Monolithic Circuits *Prerequisite: graduate standing EECS 421 or EECS 525. I odd years (4 credits)*

Theory and design of passive and active microwave components and monolithic integrated circuits including: microstrip, lumped inductors and capacitors, GaAs FETs, varactor and mixer diodes, monolithic phase shifters, attenuators, amplifiers and oscillators. Experimental characterization of the above components using network analyzer, spectrum analyzer, power and noise meters. Lecture and laboratory.

EECS 535. Optical Information Processing *Prerequisite: EECS 334. I even years (3 credits)* Theory of image formation with holography; applications of holography; white light interferometry; techniques for optical digital computing; special topics of current research interest.

EECS 536. Classical Statistical Optics *Prerequisite: EECS 334 or EECS 434, and EECS 401 or MATH 425. I odd years (3 credits)* Applications of random variables to optics; statistical properties of light waves. Coherence theory, spatial and temporal. Information retrieval; imaging through inhomogeneous media; noise processes in imaging and interferometric systems.

EECS 537 (APPPHYS 537). Classical Optics *Prerequisite: EECS 330 and EECS 334. I (3 credits)* Theory of

electromagnetic, physical, and geometrical optics. Classical theory of dispersion. Linear response, Kramers-Kronig relations, and pulse propagation. Light scattering. Geometrical optics and propagation in inhomogeneous media. Dielectric waveguides. Interferometry and theory of coherence. Diffraction, Fresnel and Fraunhofer. Gaussian beams and ABCD law.

EECS 538 (APPPHYS 550) (PHYSICS 650). Optical Waves in Crystals *Prerequisite: EECS 434. I (3 credits)*

Propagation of laser beams: Gaussian wave optics and the ABCD law. Manipulation of light by electrical, acoustical waves; crystal properties and the dielectric tensor; electro-optic, acousto-optic effects and devices. Introduction to nonlinear optics; harmonic generation, optical rectification, four-wave mixing, self-focusing, and self-phase modulation.

EECS 539 (APPPHYS 551) (PHYSICS 651). Lasers *Prerequisite: EECS 537 and EECS 538. II (3 credits)*

Complete study of laser operation: the atom-field interaction; homogeneous and inhomogeneous broadening mechanisms; atomic rate equations; gain and saturation; laser oscillation; laser resonators, modes, and cavity equations; cavity modes; laser dynamics, Q-switching and modelocking. Special topics such as femto-seconds lasers and ultrahigh power lasers.

EECS 540 (APPPHYS 540). Applied Quantum Mechanics I *Prerequisite: permission of instructor. I (3 credits)*

Introduction to nonrelativistic quantum mechanics. Summary of classical mechanics, postulates of quantum mechanics and operator formalism, stationary state problems (including quantum wells, harmonic oscillator, angular momentum theory and spin, atoms and molecules, band theory in solids), time evolution, approximation methods for time independent and time dependent interactions including electromagnetic interactions, scattering.

EECS 541 (APPPHYS 541). Applied Quantum Mechanics II *Prerequisite: EECS 540. II (3 credits)*

Continuation of nonrelativistic quantum mechanics. Advanced angular momentum theory, second quantization, non-relativistic quantum electrodynamics, advanced scattering theory, density matrix formalism, reservoir theory.

EECS 542. Vision Processing *Prerequisite: EECS 442. Alternate years (3 credits)*

Details of image formation theory, including the consideration of dynamic image sequences. The theoretical frameworks for edge detection, feature extraction, and surface description are presented. The relationship between image formation and object features is examined in detail. Programming required.

EECS 543. Knowledge-Based Systems *Prerequisite: EECS 281 and graduate standing or permission of instructor. I (3 credits)*

Techniques and principles for developing application software based on explicit representation and manipulation of domain knowledge, as applied to areas such as pattern matching, problem-solving, automated planning, and natural-language processing. Discussion of major programming approaches used in the design and development of knowledge-based systems.

EECS 545. Machine Learning *Prerequisite: EECS 492. (3 credits) II*

Survey of recent research on learning in artificial intelligence systems. Topics include learning based on examples, instructions, analogy, discovery, experimentation, observation, problem-solving and explanation. The cognitive aspects of learning will also be studied.

EECS 546 (APPPHYS 546). Ultrafast Optics *Prerequisite: EECS 537. II (3 credits)* Propagation of ultrashort optical pulses in linear and nonlinear media, and through dispersive optical elements. Laser mode-locking and ultrashort pulse generation. Chirped-pulse amplification. Experimental techniques for high time resolution. Ultrafast Optoelectronics. Survey of ultrafast high field interactions.

EECS 547 (SI 652). Electronic Commerce *Prerequisites: EECS 281 or SI 502 or permission of instructor. II (3 credits)* Introduction to the design and analysis of automated commerce systems, from both a technological and social perspective. Infrastructure supporting search for commerce opportunities, negotiating terms of trade, and executing transactions. Issues of security, privacy, incentives, and strategy.

EECS 550. Information Theory *Prerequisite: EECS 501. I (3 credits)* The concepts of source, channel, rate of transmission of information. Entropy and mutual information. The noiseless coding theorem. Noisy channels; the coding theorem for finite state zero memory channels. Channel capacity. Error bounds. Parity check codes. Source encoding.

EECS 551. Mathematical Methods for Signal Processing *Prerequisite: Preceded or accompanied by EECS 501. I (3 credits)* Linear shift-invariant systems in continuous time and discrete time. Sampling theory. Fourier analysis. Sample rate conversion. Signal representation in vector spaces. Projection theorem and least-squares approximations. Eigendecompositions and signal subspace methods. Applications in signal processing.

EECS 552 (APPPHYS 552). Fiber Optics: Internet to Biomedical Applications *Prerequisite: Any one of EECS 334, EECS 429, EECS 434, EECS 529, EECS 537, EECS 538, EECS 539 or permission of instructor. II odd years (3 credits)* This course covers the basics of fibers and applications in fields as diverse as highpower and broadband lasers, biomedical diagnostics and therapeutics, telecommunications, and internet communications. Propagation, optical amplification, and nonlinearities in fibers are discussed, and examples include transmission systems and lasers. Biomedical applications include dermatology, cardiology, and ophthalmology.

EECS 554. Introduction to Digital Communication and Coding *Prerequisite: EECS 306 and EECS 401. I (3 credits)* Digital transmission of information across discrete and analog channels. Sampling; quantization; noiseless source codes for data compression: Huffman's algorithm and entropy; block and convolutional channel codes for error correction; channel capacity; digital modulation methods: PSK, MSK, FSK, QAM; matched filter receivers. Performance analysis: power, bandwidth, data rate, and error probability.

EECS 555. Digital Communication Theory *Prerequisite: EECS 501, EECS 554. II (3 credits)* Theory of digital modulation and coding. Optimum receivers in Gaussian noise. Signal space and decision theory. Signal design. Bandwidth and dimensionality. Fundamental limits in coding and modulation. Capacity and cutoff rate. Block, convolutional and trellis coding. Continuous phase modulation. Filtered channels and intersymbol interference. Equalization. Spread-spectrum. Fading channels. Current topics.

EECS 556. Image Processing *Prerequisite: EECS 501, EECS 551. II (3 credits)* Theory and application of digital image processing. Random field models of images. Sampling, quantization, image compression, enhancement, restoration,

segmentation, shape description, reconstruction of pictures from their projections, pattern recognition. Applications include biomedical images, time-varying imagery, robotics, and optics.

EECS 557. Communication Networks *Prerequisite: graduate standing, preceded by EECS 401 or accompanied by EECS 501. I (3 credits)* System architectures. Data link control: error correction, protocol analysis, framing. Message delay: Markov processes, queuing, delays in statistical multiplexing, multiple users with reservations, limited service, priorities. Network delay: Kleinrock independence, reversibility, traffic flows, throughput analysis, Jackson networks. Multiple access networks: ALOHA and splitting protocols, carrier sensing, multi-access reservations.

EECS 558. Stochastic Control *Prerequisite: EECS 501, EECS 560. I, odd years (3 credits)* Analysis and optimization of controlled stochastic systems. Models: linear and nonlinear stochastic controlled systems, controlled Markov chains. Optimization of systems described by Markov processes; dynamic programming under perfect and imperfect information, finite and infinite horizons. System identification: off-line, recursive. Stochastic adaptive control: Markov chains, self-tuning regulators, bandit problems.

EECS 559. Advanced Signal Processing *Prerequisite: EECS 551 and EECS 501. I (3 credits)* Estimators of second order properties of random processes: nonparametric and model-based techniques of spectral estimation, characterization of output statistics for nonlinear systems, time-frequency representations. Performance evaluation using asymptotic techniques and Monte Carlo simulation. Applications include speech processing, signal extrapolation, multidimensional spectral estimation, and beamforming.

EECS 560 (AEROSP 550) (MECHENG 564). Linear Systems Theory *Prerequisite: graduate standing. I (4 credits)* Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability, observability, realizations, canonical decomposition, stability.

EECS 561 (MECHENG 561). Design of Digital Control Systems *Prerequisite: EECS 460 or MECHENG 461. I (3 credits)* Sampling and data reconstruction. Z-transforms and state variable descriptions of discrete-time systems. Modeling and identification. Analysis and design using root locus, frequency response, and state space techniques. Linear quadratic optimal control and state estimation. Quantization and other nonlinearities.

EECS 562 (AEROSP 551). Nonlinear Systems and Control *Prerequisite: graduate standing. II (3 credits)* Introduction to the analysis and design of nonlinear systems and nonlinear control systems. Stability analysis using Liapunov, input-output and asymptotic methods. Design of stabilizing controllers using a variety of methods: linearization, absolute stability theory, vibrational control, sliding modes and feedback linearization.

EECS 564. Estimation, Filtering, and Detection *Prerequisite: EECS 501. II (3 credits)* Principles of estimation, linear filtering and detection. Estimation: linear and nonlinear minimum mean squared error estimation, and other strategies. Linear filtering: Wiener and Kalman filtering. Detection: simple, composite, binary and multiple hypotheses. Neyman-

Pearson and Bayesian approaches.

EECS 565 (AEROSP 580). Linear Feedback Control Systems *Prerequisite: EECS 460 or AEROSP 348 or MECHENG 461 and AEROSP 550 (EECS 560). II (3 credits)* Control design concepts for linear multivariable systems. Review of single variable systems and extensions to multivariable systems. Purpose of feedback. Sensitivity, robustness, and design tradeoffs. Design formulations using both frequency domain and state space descriptions. Pole placement/observer design. Linear quadratic Gaussian based design methods. Design problems unique to multivariable systems.

EECS 567 (MFG 567) (MECHENG 567). Introduction to Robotics *Prerequisite: graduate standing or permission of instructor (3 credits)* Introduction to the central topics in robotics, including geometry, kinematics, differential kinematics, dynamics, and control of robot manipulators. The mathematical tools required to describe spatial motion of a rigid body will be presented in full. Motion planning including obstacle avoidance is also covered.

EECS 568 (NAVARCH 568). Mobile Robotics: Methods and Algorithms *Prerequisite: Graduate Standing or permission of instructor. (4 credits)* Theory and applications of probabilistic techniques for autonomous mobile robotics. This course will present and critically examine contemporary algorithms for robot perception (using a variety of modalities), state estimation, mapping, and path planning. Topics include Bayesian filtering; stochastic representations of the environment; motion and sensor models for mobile robots; algorithms for mapping, localization, planning and control in the presence of uncertainty; application to autonomous marine, ground, and air vehicles.

EECS 569. Production Systems Engineering *Prerequisite: none. II Alternate Years (3 credits)* Production systems in large volume manufacturing (e.g., automotive, semiconductor, computer, etc.) are studied. Topics include quantitative methods for analysis of production systems; analytical methods for design of lean in-process and finished goods buffering; measurement-based methods for identification and elimination of production system bottlenecks; and system-theoretic properties of production lines.

EECS 570. Parallel Computer Architecture *Prerequisite: EECS 470. II (4 credits)* Architectures for explicit parallelism. Multithreaded processors, small- and large-scale multiprocessor systems. Shared-memory coherence and consistency. Effect of architecture on communication latency, bandwidth, and overhead. Latency tolerance techniques. Interconnection networks. Case studies. Term projects.

EECS 571. Principles of Real-Time Computing *Prerequisite: EECS 470, EECS 482 or permission of instructor. I (4 credits)* Principles of real-time computing based on high performance, ultra reliability and environmental interface. Architectures, algorithms, operating systems and applications that deal with time as the most important resource. Real-time scheduling, communications and performance evaluation.

EECS 573. Microarchitecture *Prerequisite: EECS 470 or permission of instructor. I alternate years (3 credits)* Graduate-level introduction to the foundations of high performance microprocessor implementation. Problems involving instruction supply, data supply, and instruction processing. Compile-time vs. run-time tradeoffs. Aggressive branch

prediction. Wide-issue processors, in-order vs. out-of-order execution, instruction retirement. Case studies taken from current microprocessors.

EECS 574. Computational Complexity *Prerequisite: EECS 376 or graduate standing. I (4 credits)* Fundamentals of the theory of computation and complexity theory. Computability, undecidability, and logic. Relations between complexity classes, NP-completeness, P-completeness, and randomized computation. Applications in selected areas such as cryptography, logic programming, theorem proving, approximation of optimization problems, or parallel computing.

EECS 575. Advanced Cryptography *Prerequisite: EECS 203 or equivalent (EECS 574 recommended) II. (4 credits)* A rigorous introduction to the design of cryptosystems and to cryptanalysis. Topics include cryptanalysis of classical cryptosystems; theoretical analysis of one-way functions; DES and differential cryptanalysis; the RSA cryptosystem; ElGamal, elliptic, hyperelliptic and hidden monomial cryptosystems; attacks on signature schemes, identification schemes and authentication codes; secret sharing; and zero knowledge.

EECS 578. Computer-Aided Design Verification of Digital Systems *Prerequisite: EECS 478 or graduate standing. Every third term I or II (4 credits)* Design specification vs. implementation. Design errors. Functional and temporal modeling of digital systems. Simulation vs. symbolic verification techniques. Functional verification of combinational and sequential circuits. Topological and functional path delays; path sensitization. Timing verification of combinational and sequential circuits. Clock schedule optimization.

EECS 579. Digital System Testing *Prerequisite: graduate standing. Every third term I or II (4 credits)* Overview of fault-tolerant computing. Fault sources and models. Testing process. Combinational circuit testing. D-Algorithm and PODEM. Sequential circuit testing. Checking experiments. RAM and microprocessor testing. Fault simulation. Design for testability. Testability measures. Self-testing circuits and systems.

EECS 580. Advanced Computer Graphics *Prerequisite: EECS 487 (or equivalent) or graduate standing. II (4 credits)* Geometric modeling: spline curves and surfaces, subdivision surfaces, polygonal meshes, point-based and implicit surfaces. Real-time rendering: fixed and programmable pipeline, shadows. Acceleration algorithms: culling and level-of-detail. Collision detection. Delaunay triangulations and Voronoi diagrams. Non-photorealistic rendering. Pattern synthesis. Image-based rendering.

EECS 581. Software Engineering Tools *Prerequisite: EECS 481 or equivalent programming experience. II (3 credits)* Fundamental areas of software engineering including life-cycle-paradigms, metrics, and tools. Information hiding architecture, modular languages, design methodologies, incremental programming, and very high level languages.

EECS 582. Advanced Operating Systems *Prerequisite: EECS 482. II (4 credits)* Course discusses advanced topics and research issues in operating systems. Topics will be drawn from a variety of operating systems areas such as distributed systems and languages, networking, security, and protection, real-time systems, modeling and analysis, etc.

EECS 583. Advanced Compilers *Prerequisite: EECS 281 and 370 (EECS 483 is also recommended) I (4 credits)* In-

depth study of compiler back-end design for high-performance architectures. Topics include control-flow and data-flow analysis, optimization, instruction scheduling, register allocation. Advanced topics include memory hierarchy management, instruction-level parallelism, predicated and speculative execution. The class focus is processor-specific compilation techniques, thus familiarity with both computer architecture and compilers is recommended.

EECS 584. Advanced Database Systems *Prerequisite: EECS 484 or permission of instructor. I (4 credits)* Advanced topics and research issues in database management systems. Distributed databases, advanced query optimization, query processing, transaction processing, data models and architectures. Data management for emerging application areas, including bioinformatics, the internet, OLAP, and data mining. A substantial course project allows in-depth exploration of topics of interest.

EECS 586. Design and Analysis of Algorithms *Prerequisite: EECS 281. II (4 credits)* Design of algorithms for nonnumeric problems involving sorting, searching, scheduling, graph theory, and geometry. Design techniques such as approximation, branch-and-bound, divide-and-conquer, dynamic programming, greed, and randomization applied to polynomial and NP-hard problems. Analysis of time and space utilization.

EECS 587. Parallel Computing *Prerequisite: EECS 281 and graduate standing. I (4 credits)* The development of programs for parallel computers. Basic concepts such as speedup, load balancing, latency, system taxonomies. Design of algorithms for idealized models. Programming on parallel systems such as shared or distributed memory machines, networks. Grid Computing. Performance analysis. Course includes a substantial term project.

EECS 588. Computer and Network Security *Prerequisite: EECS 482 or EECS 489 or graduate standing. II (4 credits)* Survey of advanced topics and research issues in computer and network security. Topics will be drawn from a variety of areas such as mandatory and discretionary security policies, secure storage, security kernels, trust management, preventing software vulnerabilities, applied cryptography, network security.

EECS 589. Advanced Computer Networks *Prerequisite: EECS 489. I (4 credits)* Advanced topics and research issues in computer networks. Topics include routing protocols, multicast delivery, congestion control, quality of service support, network security, pricing and accounting, and wireless access and mobile networking. Emphasis is placed on performance trade-offs in protocol and architecture designs. Readings assigned from research publications. A course project allows in-depth exploration of topics of interest.

EECS 590. Advanced Programming Languages *Prerequisite: EECS 281 or equivalent. II (4 credits)* Fundamental concepts in Programming Languages (PL) as well as recent topics and trends in PL research. Topics include semantics, type systems, program verification using theorem provers, software model checking, and program analysis. Course focuses on applying PL concepts to improve software reliability. Course includes semester long individual research project.

EECS 591. Distributed Systems *Prerequisite: EECS 482 and graduate standing. I (4 credits)* Principles and practice of distributed system design. Computations, consistency semantics, and failure models. Programming paradigms including

group communication, RPC, distributed shared memory, and distributed objects. Operating system kernel support; distributed system services including replication, caching, file system management, naming, clock synchronization, and multicast communication. Case studies.

EECS 592. Advanced Artificial Intelligence *Prerequisite: EECS 492 or permission of instructor. II (4 credits)*

Advanced topics in artificial intelligence. Issues in knowledge representation, knowledge-based systems, problem solving, planning and other topics will be discussed. Students will work on several projects.

EECS 594. Introduction to Adaptive Systems *Prerequisite: EECS 203, MATH 425 (Stat 425). Alternate years (3*

credits) Programs and automata that "learn" by adapting to their environment; programs that utilize genetic algorithms for learning. Samuel's strategies, realistic neural networks, connectionist systems, classifier systems, and related models of cognition. Artificial intelligence systems, such as NETL and SOAR, are examined for their impact upon machine learning and cognitive science.

EECS 595 (LING 541) (SI 561). Natural Language Processing *Prerequisite: Senior Standing. I (3 credits)* Course is

an introduction to computational and linguistic concepts and techniques for modeling and analyzing natural language. Topics include finite-state machines, part of speech tagging, context-free grammars, syntax and parsing, unification grammars and unification-based parsing, language and complexity, semantics, discourse and dialogue modeling, natural language generation, and machine translation.

EECS 596. Master of Engineering Team Project *Prerequisite: enrollment in the Masters of Engineering program in*

EECS. I, II, IIIa, IIIb, and III (1-6 credits) To be elected by EECS students pursuing the Master of Engineering degree. Students are expected to work in project teams. May be taken more than once up to a total of 6 credit hours.

EECS 597 (SI 760) (LING 702). Language and Information *Prerequisite: SI 503 or EECS 281 and graduate standing*

or permission of instructor. I alternate years (3 credits) A survey of techniques used in language studies and information processing. Students will learn how to explore and analyze textual data in the context of Web-based information retrieval systems. At the conclusion of the course, students will be able to work as information designers and analysts.

EECS 598. Special Topics in Electrical Engineering and Computer Science *Prerequisite: permission of instructor or*

counselor. I, II, IIIa, IIIb, and III (1-4 credits) Topics of current interest in electrical engineering and computer science. Lectures, seminar, or laboratory. Can be taken more than once for credit.

EECS 599. Directed Study *Prerequisite: prior arrangement with instructor; mandatory satisfactory/unsatisfactory. I,*

II, IIIa, IIIb and III (1-4 credits) Individual study of selected advanced topics in electrical engineering and computer science. May include experimental work or reading. Primarily for graduate students. To be graded on satisfactory/unsatisfactory basis ONLY.

EECS 600 (IOE 600). Function Space Methods in System Theory *Prerequisite: Math 419. II (3 credits)* Introduction

to the description and analysis of systems using function analytic methods. Metric spaces, normed linear spaces, Hilbert

spaces, resolution spaces. Emphasis on using these concepts in systems problems.

EECS 627. VLSI Design II *Prerequisite: EECS 427. II (4 credits)* Advanced very large scale integrated (VLSI) circuit design. Design methodologies (architectural simulation, hardware description language design entry, silicon compilation, and verification), microarchitectures, interconnect, packaging, noise sources, circuit techniques, design for testability, design rules, VLSI technologies (silicon and GaAs), and yield. Projects in chip design.

EECS 628. Advanced High Performance VLSI Design *Prerequisite: EECS 627 or equivalent. I Alternate years (3 credits)* Advanced issues in VLSI design addressing the areas of high performance, low power and reliability. Topics covered include recent approaches in leakage control, high speed on-chip communication, memory design, soft error failures, noise analysis and control, error tolerant design, and new circuit families. Students will complete an advanced project.

EECS 631. Electromagnetic Scattering *Prerequisite: EECS 530 and graduate standing. Alternate years (3 credits)* Boundary conditions, field representations. Low and high frequency scattering. Scattering by half plane (Wiener-Hopf method) and wedge (Maliuzhinets method); edge diffraction. Scattering by a cylinder and sphere: Watson transformation, Airy and Fock functions, creeping waves. Geometrical and physical theories of diffraction.

EECS 632. Microwave Remote Sensing II - Radar *Prerequisite: EECS 532. II Even years (3 credits)* Radar equation; noise statistics; resolution techniques; calibration; synthetic aperture radar; scatterometers; scattering models; surface and volume scattering; land and oceanographic applications.

EECS 633. Numerical Methods in Electromagnetics *Prerequisite: EECS 530. Alternate years (3 credits)* Numerical techniques for antennas and scattering; integral representation: solutions of integral equations: method of moments, Galerkin's technique, conjugate gradient FFT; finite element methods for 2-D and 3-D simulations; hybrid finite element/boundary integral methods; applications: wire, patch and planar arrays; scattering composite structures.

EECS 634 (APPPHYS 611) (PHYSICS 611). Nonlinear Optics *Prerequisite: EECS 537 or EECS 538 or EECS 530. I (3 credits)* Formalism of wave propagation in nonlinear media; susceptibility tensor; second harmonic generation and three-wave mixing; phase matching; third order nonlinearities and four-wave mixing processes; stimulated Raman and Brillouin scattering. Special topics: nonlinear optics in fibers, including solitons and self-phase modulation.

EECS 638 (APPPHYS 609) (PHYSICS 542). Quantum Theory of Light *Prerequisite: quantum mechanics, electrodynamics, atomic physics. II (3 credits)* The atom-field interaction; density matrix; quantum theory of radiation including spontaneous emission; optical Bloch equations and theory of resonance fluorescence; coherent pulse propagation; dressed atoms and squeezed states; special topics in nonlinear optics.

EECS 643 (PSYCH 643). Theory of Neural Computation *Prerequisite: graduate standing or permission of instructor. II Alternate years (2-4 credits)* This course will review computational models of human cognitive processes with four goals in mind: (1) to learn about the wide variety of approaches to cognitive modeling (e.g., self-organizing nets, multi-

layer nets, and back-propagation, production systems, ACT*, EPIC, Soar...) and the advantages and disadvantages of each, (2) to study some of the most important cognitive models of specific domains (e.g., dual task performance, reasoning, explicit learning, working memory), (3) to evaluate when cognitive modeling is an appropriate and useful research strategy, and (4) to give students an opportunity to gain hands-on experience in implementing their own cognitive models. Students will be expected to take turns in leading discussion of specific papers and to work in groups in implementing a computational model.

EECS 644 (PSYCH 644). Computational Modeling of Cognition *Prerequisite: graduate standing or permission of instructor. II Alternate years (2-4 credits)* This course will examine computational models of human cognitive processes. Course goals include learning about important computational models of specific cognitive domains and evaluating the appropriateness and utility of different computational approaches to substantive problems in cognition.

EECS 650. Channel Coding Theory *Prerequisite: EECS 501 and MATH 419. II Alternate years (3 credits)* The theory of channel coding for reliable communication and computer memories. Error correcting codes; linear, cyclic and convolutional codes; encoding and decoding algorithms; performance evaluation of codes on a variety of channels.

EECS 651. Source Coding Theory *Prerequisite: EECS 501. II odd years (3 credits)* Introduction to a variety of source coding techniques such as quantization, block quantization; and differential, predictive, transform and tree coding. Introduction to rate-distortion theory. Applications include speech and image coding.

EECS 659. Adaptive Signal Processing *Prerequisite: EECS 564. I odd years (3 credits)* Theory and applications of adaptive filtering in systems and signal processing. Iterative methods of optimization and their convergence properties: transversal filters; LMS (gradient) algorithms. Adaptive Kalman filtering and least-squares algorithms. Specialized structures for implementation: e.g., least-squares lattice filters, systolic arrays. Applications to detection, noise canceling, speech processing, and beam forming.

EECS 661. Discrete Event Systems *Prerequisite: graduate standing. I even years (3 credits)* Modeling, analysis, and control of discrete event systems; untimed (logical) and timed models considered. Defining characteristics of discrete event systems. Logical models: languages, automata, and Petri nets. Analysis: safety, blocking, state estimation and diagnostics. Supervisory control: controllability, nonblocking and nonconflicting languages, observability and co-observability. Timed models: timed automata and timed Petri nets. Analysis using dioid algebras. Control of Petri nets. Introduction to stochastic models.

EECS 662 (MECHENG 662). Advanced Nonlinear Control *Prerequisite: EECS 562 or MECHENG 548. I (3 credits)* Geometric and algebraic approaches to the analysis and design of nonlinear control systems. Nonlinear controllability and observability, feedback stabilization and linearization, asymptotic observers, tracking problems, trajectory generation, zero dynamics and inverse systems, singular perturbations, and vibrational control.

EECS 670. Special Topics in Computer Architecture *Prerequisite: permission of instructor. (3 credits)* Current topics of interest in computer architecture. This course may be repeated for credit.

EECS 674. Special Topics in Theoretical Computer Science *Prerequisite: permission of instructor. (3 credits)* Current topics of interest in theoretical computer science. This course may be repeated for credit.

EECS 682. Special Topics in Software Systems *Prerequisite: permission of instructor. (3 credits)* Current topics of interest in software systems. This course may be repeated for credit.

EECS 684. Current Topics in Databases *Prerequisite: EECS 484. I (3 credits)* Research issues in database systems chosen for in-depth study. Selected topics such as spatial, temporal, or real-time databases; data mining, data warehousing, or other emerging applications. Readings from recent research papers. Group projects.

EECS 691. Mobile Computing *Prerequisite: EECS 582 or EECS 589 or EECS 591 or equivalent. II Alternate years. (3 credits)* In-depth study of research issues in mobile and pervasive computing systems. Topics include location and context awareness, mobile data access, resource management, consistency protocols, mobile and ad hoc networking, networked sensors, security and privacy.

EECS 692. Special Topics in Artificial Intelligence *Prerequisites: permission of instructor. (3 credits)* Current topics of interest in artificial intelligence. This course can be repeated for credit.

EECS 695 (PSYCH 740). Neural Models and Psychological Processes *Prerequisite: permission of instructor. II (3 credits)* Consideration of adaptively and biologically oriented theories of human behavior. Emphasis on both the potential breadth of application and intuitive reasonableness of various models. There is a bias toward large theories and small simulations.

EECS 698. Master's Thesis *Prerequisite: election of an EECS master's thesis option. I, II, IIIa, IIIb, and III (1-6 credits)* To be elected by EE and EES students pursuing the master's thesis option. May be taken more than once up to a total of 6 credit hours. To be graded on a satisfactory/unsatisfactory basis ONLY.

EECS 699. Research Work in Electrical Engineering and Computer Science *Prerequisite: graduate standing, permission of instructor; mandatory satisfactory/unsatisfactory. I, II, IIIa, IIIb, III (1-6 credits)* Students working under the supervision of a faculty member plan and execute a research project. A formal report must be submitted. May be taken for credit more than once up to a total of 6 credit hours. To be graded satisfactory/unsatisfactory ONLY.

EECS 700. Special Topics in System Theory *Prerequisite: permission of instructor (to be arranged)*

EECS 720. Special Topics in Solid-State Devices, Integrated Circuits, and Physical Electronics *Prerequisite: permission of instructor. (1-4 credits)* Special topics of current interest in solid-state devices, integrated circuits, microwave devices, quantum devices, noise, plasmas. This course may be taken for credit more than once.

EECS 730. Special Topics in Electromagnetics *Prerequisite: permission of instructor. (1-4 credits) (to be arranged)*

EECS 735. Special Topics in the Optical Sciences *Prerequisite: graduate standing, permission of instructor (to be*

arranged) (1-4 credits) Key topics of current research interest in ultrafast phenomena, short wavelength lasers, atomic traps, integrated optics, nonlinear optics and spectroscopy. This course may be taken for credit more than once under different instructors.

EECS 750. Special Topics in Communication and Information Theory *Prerequisite: permission of instructor. (to be arranged)*

EECS 755. Special Topics in Signal Processing *Prerequisite: permission of instructor. (to be arranged)* (1-4 credits) Advanced topics in Signal and/or image processing. The specific topics vary with each offering. This course may be taken for credit more than once.

EECS 760. Special Topics in Control Theory *Prerequisite: permission of instructor. (to be arranged)*

EECS 765. Special Topics in Stochastic Systems and Control *Prerequisite: permission of instructor. (to be arranged)* (3 credits) Advanced topics on stochastic systems such as stochastic calculus, nonlinear filtering, stochastic adaptive control, decentralized control, and queuing networks.

EECS 767 (SI 767). Advanced Natural Language Processing and Information Retrieval *Prerequisite: SI 661, SI 761, or SI 760 or permission of instructor. II* (3 credits) Course is focused on reading recent research papers on topics in natural-language processing and information retrieval, such as statistical machine translation, expectation maximization, text classification, sentiment and polarity analysis, information extraction using conditional random fields, document models for information retrieval, semi-supervised learning, and latent semantic analysis. The course is appropriate for students who have already taken either of the following classes: "Natural Language Processing," "Information Retrieval," and/or "Language and Information."

EECS 770. Special Topics in Computer Systems *Prerequisite: permission of instructor. (to be arranged)* **EECS 792. Advanced AI Techniques** *Prerequisite: EECS 492. II* (3 credits) Formulating and solving problems using artificial intelligence techniques. Projects employ advanced methods from knowledge representation, search, machine learning, and other AI areas. This is a component of the Intelligent Systems qualification process.

EECS 820. Seminar in Solid-State Electronics *Prerequisite: graduate standing, permission of instructor. I* (1 credit) Advanced graduate seminar devoted to discussing current research topics in areas of solid-state electronics. Specific topics vary each time the course is offered. Course may be elected more than once.

EECS 892. Seminar in Artificial Intelligence *Prerequisite: EECS 592 or equivalent. I, II* (2 credits) Advanced graduate seminar devoted to discussing current research papers in artificial intelligence. The specific topics vary each time the course is offered.

EECS 990. Dissertation/Pre-Candidate I, II, III (2-8 credits); **IIIa, IIIb** (1-4 credits) Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be

held under a full-term candidacy enrollment.

EECS 995. Dissertation/Candidate *Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, III (8 credits); IIIa, IIIb (4 credits)* Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

EECS courses as of 9/10

10. ADDITIONAL INFORMATION AND FORMS

Various current forms such as the master's degree plan of study are available on the CSE Graduate Website:

<http://www.eecs.umich.edu/eecs/graduate/cse/csegradpage.html>