SCHOOL OF ENGINEERING

ELECTRICAL ENGINEERING

Emeriti: (Professors) Clayton W. Bates, Richard Bube,* John Cioffi, Von R. Eshleman, Michael J. Flynn,* Gene F. Franklin, Joseph W. Goodman, Robert A. Helliwell, Martin E. Hellman,* Thomas Kailath,* Gordon S. Kino, John G. Linvill,* Albert Macovski, Laurence A. Manning,* Edward J. McCluskey, Malcolm M. McWhorter, James D. Meindl,* Richard H. Pantell, Anthony E. Siegman,* Leonard Tyler, Robert L. White; (*Associate Professor*) Bruce B. Lusignan; *(Professors, Research)* Donald L. Carpenter,* Aldo da Rosa,* Antony Fraser-Smith, C. Robert Helms,* Ingolf Lindau, David Luckham, Calvin F. Quate

Chair: Mark Horowitz
Vice Chair: Simon Wong
Associate Chair (Admissions): Howard Zebker
Assistant Chair : TBD

Professors: Nicholas Bambos, Stephen P. Boyd, Thomas M. Cover, Donald C. Cox, William J. Dally, Robert W. Dutton, Abbas El Gamal, Hector Garcia-Molina, Bernd Girod, Andrea G. Goldsmith, Robert M. Gray, Patrick Hanrahan, James S. Harris, Stephen E. Harris, John L. Hennessy, Lambertus Hesselink, Mark A. Horowitz, Roger T. Howe, Umran S. Inan, Joseph M. Kahn, Gregory T. A. Kovacs, Thomas H. Lee, Marc Levoy, Teresa H. Y. Meng, David A. B. Miller, Dwight G. Nishimura, Oyekunle Olukotun, Brad G. Osgood, John Pauly, R. Fabian W. Pease, James D. Plummer, Krishna Saraswat, Fouad A. Tobagi, Shan X. Wang, Jennifer Widom, Bernard Widrow, H. S. Philip Wong, S. Simon Wong, Bruce A. Wooley, Yoshihisa Yamamoto, Howard Zebker

Associate Professors: Dan Boneh, Dawson Engler, Shanhui Fan, John T. Gill III, Christoforos E. Kozyrakis, Sanjay Lall, Nick McKeown, Balaji Prabhakar, Mendel Rosenblum, Krishna V. Shenoy, Olav Solgaard, Sebastian Thrun, Benjamin Van Roy, Jelena Vuckovic

Assistant Professors: Sachin Katti, Philip Levis, Subhasish Mitra, Andrea Montanari, Ada Poon, Boris Murmann, Peter Peumans, Tsachy Weissman

Professors (Research): James F. Gibbons, Leonid Kazovsky, Butrus Khuri-Yakub, Yoshio Nishi, Arogyaswami J. Paulraj, Piero Pianetta

Acting Assistant Professor: Laurent Giovangrandi, Jaeha Kim

Courtesy Professors: Stacey Bent, John Bravman, David Cheriton, Amir Dembo, David L. Dill, Per Enge, Gary Glover, Peter Glynn, Leonidas Guibas, Monica S. Lam, David G. Luenberger, John C. Mitchell, Sandy Napel, Richard Olshen, Norbert Pelc, Zhi-Xun Shen, Julius Smith, Claire Tomlin, Brian Wandell, Yinyu Ye, Shoucheng Zhang

Courtesy Associate Professors: Kwabena Boahen, David Mazieres, Michael McConnell, Daniel Spielman

Courtesy Assistant Professors: Kerwyn C. Huang, Ramesh Johari, Hari Manoharan, Andrew Ng, Gunter Niemeyer, Amin Saberi

Lecturers: Dennis Allison, Michel Digonnet, Andrew Freeman, Roger Melen, Dieter Scherer, Jason Stinson, Howard Swain, James Weaver

Consulting Professors: Hamid Aghaian, Ahmad Bahai, Richard Dasher, John Doolittle, Leslie Field, Silvano Gai, Fred M. Gibbons, Dimitry Gorinevsky, Bertrand Hochwald, Bob S. Hu, Theodore Kamins, Rajeev Krishnamoorhy, David Leeson, Madihally Narasimha, Gurudatta Parulkar, Ronald Schafer, Donald Stark, David Su, Simon Sze, Martin Walt, John Wenstrand,

Consulting Associate Professors: Edward Chan, Micah Siegel, Katelin Vleugels, Jun Ye

Consulting Assistant Professors: Guido Appenzeller, Kamesh Medapalli, Daniel O'Neill, Jatinder Singh

Visiting Professors: David Larrabeiti Lopez, Byoung Ho Lee, Yuribiko Nakata, Yisk Oh, Bob Wahlberg, Zhiping Yu

Visiting Associate Professors: Ramesh Abhari, Sunghyun Choi, David Elata, Yonina Eldar, Jun Obeki, Xiaofeng Tao

Visiting Assistant Professors: Divanilson Campelo, Ofer Levi, Ashwin Seshia

* recalled to active duty

Mail Code: 94305-9505
Phone: (650) 723-3931; Fax: (650) 723-1882
Web Site: http://ee.stanford.edu

Courses offered by the Department of Electrical Engineering are listed under the subject code EE on the *Stanford Bulletin's* ExploreCourses web site.

ELECTRICAL ENGINEERING COURSE CATALOG NUMBERING SYSTEM

Electrical Engineering courses are typically numbered according to the year in which the courses are normally taken.

010-099	first or second year
100-199	second through fourth year
200-299	mezzanine courses for advanced undergraduates or graduates
300-399	first graduate year
400-499	second or third graduate year
600-799	special summer courses

The Department of Electrical Engineering (EE) offers courses in the following areas:

Communication Systems
Computer Hardware
Computer Software Systems
Control and System Engineering
Dynamic Systems and Optimization
Electronic Circuits
Electronic Devices, Sensors, and Technology
Fields, Waves, and Radioscience
Image Systems
Lasers, Optoelectronics, and Quantum Electronics
Network Systems
Signal Processing
Solid State Materials and Devices

UNDERGRADUATE PROGRAMS IN ELECTRICAL ENGINEERING

The mission of the undergraduate program of the Department of Electrical Engineering is to augment the liberal education expected of all Stanford undergraduates and impart a basic understanding of electrical engineering built on a foundation of physical science, mathematics, computing, and technology.

Graduates of the undergraduate program are expected to possess knowledge of the fundamentals of electrical engineering and at least one specialty area. The graduates are expected to have the basic experimental, design, and communication skills to be prepared for continued study at the graduate level or for entry-level positions that require a basic knowledge of electrical engineering, science, and technology.

The educational objectives of the program are:

1. Technical knowledge: provide a basic knowledge of electrical engineering principles along with the required supporting knowledge of computing, engineering fundamentals, mathematics, and science. The program must include depth in at least one specialty area, currently including computer hardware, computer software, controls, circuits, fields and waves, communication and signal processing, and semiconductor and photonic devices.

2. Laboratory and design skills: develop the basic skills needed to perform and design experimental projects. Develop the ability to formulate problems and projects and to plan a process for

solution, taking advantage of diverse technical knowledge and skills.

3. Communications skills: develop the ability to organize and present information and to write and speak effective English.
4. Preparation for further study: provide sufficient breadth and depth for successful subsequent graduate study, postgraduate study, or lifelong learning programs.
5. Preparation for the profession: provide an appreciation for the broad spectrum of issues arising in professional practice, including economics, ethics, leadership, professional organizations, safety, service, and teamwork.

To major in Electrical Engineering (EE), undergraduates should follow the depth sequence given in the discussion of undergraduate programs in the "School of Engineering" section of this bulletin. Students are required to have a program planning sheet approved by their adviser and the department prior to the end of the quarter following the quarter in which they declare their major and at least one year prior to graduation. Program sheets for the general EE requirements and for each of the EE specialty sequences may be found at http://ughb.stanford.edu. Majors must receive at least a 2.0 grade point average (GPA) in courses taken for the EE depth requirement; all classes must be taken for a letter grade.

For information about an EE minor, see the "School of Engineering" section of this bulletin.

A Stanford undergraduate may work simultaneously toward the B.S. and M.S. degrees. See "Dual and Coterminal Degree Programs" in the "School of Engineering" section of this bulletin.

For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/shared/publications.htm#Coterm.

HONORS PROGRAM

The Department of Electrical Engineering offers a program leading to a Bachelor of Science in Electrical Engineering with honors. This program offers a unique opportunity for qualified undergraduate majors to conduct independent study and research at an advanced level with a faculty mentor, graduate students, and fellow undergraduates.

Admission to the honors program is by application. Declared EE majors with a grade point average (GPA) of at least 3.5 in Electrical Engineering are eligible to submit an application. Applications must be submitted by Autumn quarter of the senior year, be signed by the thesis adviser and second reader (one must be a member of the EE Faculty), and include an honors proposal. Students need to declare honors on Axess.

In order to receive departmental honors, students admitted to the honors program must:

1. maintain a grade point average (GPA) of at least 3.5 in EE courses.
2. complete at least 10 units of EE 191 for a letter grade with their project adviser.
3. submit two final copies of the honors thesis approved by the adviser and second reader.
4. attend poster and oral presentation in the Electrical Engineering Honors Symposium held at the end of Spring Quarter or present in another suitable forum approved by the faculty adviser.

GRADUATE PROGRAMS IN ELECTRICAL ENGINEERING

University regulations governing the M.S., Engineer, and Ph.D. degrees are described in the "Graduate Degrees" section of this bulletin.

The profession of electrical engineering demands a strong foundation in physical science and mathematics, a broad knowledge of engineering techniques, and an understanding of the relationship between technology and man. Curricula at Stanford are planned to offer the breadth of education and depth of training necessary for leadership in the profession. To engage in this profession with competence, four years of undergraduate study and at least one year of postgraduate study are recommended. For those who plan to work in highly technical development or fundamental research, additional graduate study is desirable.

A one- to two-year program of graduate study in Electrical Engineering may lead to the degree of Master of Science. The program is typically completed in five academic quarters. A two- to three-year program, offering a wider selection of engineering course work, more opportunity for study in the related fields of engineering, mathematics, and physics, and in particular, more independent work and individual guidance, may lead to the degree of Engineer.

The degree of Doctor of Philosophy is offered under the general regulations of the University. The doctoral program, requiring a minimum of 135 units of graduate study, should be considered by those with the ability and desire to make a life work of research or teaching.

Application for Admission—Applications for admission with graduate standing in Electrical Engineering (EE) should be completed electronically at http://gradadmissions.stanford.edu. For more information concerning Electrical Engineering graduate admissions, see http://ee-admissions.stanford.edu. The application deadline for admission for Autumn Quarter 2010-11 is December 15, 2009.

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

Students with undergraduate degrees in physics, mathematics, or related sciences, as well as in various branches of engineering, are invited to apply for admission. They should typically be able to complete the master's degree in five academic quarters; note that many courses are not taught during the summer. Students with undergraduate degrees in other fields may also be admitted for graduate study; see below.

The master's degree program may provide advanced preparation for professional practice or for teaching at the junior college level, or it may serve as the first step in graduate work leading to the degree of Engineer or Ph.D. The faculty does not prescribe specific courses to be taken. Each student, with the help of a program adviser, prepares an individual program and submits it to the faculty for approval. The master's program proposal must be submitted to the department office during the first quarter of graduate study; modifications may be made until one quarter prior to degree conferral. Detailed requirements and instructions are in the *Handbook for Graduate Students in Electrical Engineering at Stanford University* (http://ee.stanford.edu/gradhandbook). Programs of at least 45 units that meet the following guidelines are normally approved. Cognate (extradepartmental) courses of the appropriate level are considered as Electrical Engineering courses.

1. A sequence of three or more letter-graded electrical engineering courses numbered above 200, to provide depth in one area. The student must maintain an average 3.0 grade point average (GPA) or better in both the depth area and overall.
2. At least one letter-graded EE course numbered above 200 in each of three distinct course areas outside of the area selected under item 1 to provide breadth. Two courses are not considered to be in distinct areas if they can be found under a common depth area.
3. Enough additional units of EE courses so that items 1 through 3 total at least 21 units of letter-graded EE courses numbered above 200, including at least 9 units of such courses numbered in the 300s or 400s. Some 600- or 700-level summer courses may also be considered for inclusion in the M.S. program. Special studies units may not be used.
4. Additional course work to bring the total to 45 or more quarter units, including:
   a. at least 36 letter-graded units
   b. at least 36 units at or above the 100 level
   c. at least 30 units in technical areas such as engineering, mathematics, and science; thesis and special studies units cannot be included.

5. Either (a) one formal EE seminar course for credit, or (b) attend a minimum of eight informal or formal EE research seminars, and submit with the final M.S. program a list of the seminars with a paragraph describing the content and the signature of the M.S. adviser. This requirement is to ensure that students sample the many available research seminars.

Capable students without formal undergraduate preparation in electrical engineering may also be admitted for graduate study. Such students may have graduated in any field and may hold either the B.S. or B.A. degree. Each student, with the help of an adviser, prepares a program of study to meet particular needs and submits it to the faculty for approval. A student with adequate preparation in mathematics through calculus and college physics including electricity can usually complete the M.S. degree requirements within two academic years. A student with some additional preparation in electrical engineering may be able to complete the M.S. requirements in only one academic year.

Graduate study in EE demands that students be adequately prepared in circuits, digital systems, fields, lab work, mathematics, and physics. Skill in using modern computing facilities is essential for electrical engineers, and an increasing number of courses routinely require it. This skill should be acquired early in the program, either by taking one of the regular computer science courses or one of the special short courses given by the Computation Center, or by self-study.

It is the student's responsibility, in consultation with an adviser, to determine whether the prerequisites for advanced courses have been met. Prerequisite courses ordinarily taken by undergraduates may be included as part of the graduate program of study. However, if the number of these is large, the proposed program may contain more than the typical 45 units, and the time required to meet the degree requirements may be increased.

Students working toward the Master of Science degree in Electrical Engineering who are considering a Ph.D. or Engineer degree program in Electrical Engineering at Stanford must request the addition of a new degree program by submitting a Graduate Program Authorization Petition for approval by the department. The petition must be submitted and approved at least one quarter prior to M.S. degree completion. Once the M.S. degree in EE has been conferred, a student may not register for additional course work without this approval. Permission to study beyond the M.S. degree is normally granted to students who were originally admitted to the Ph.D. program if the student:

1. has passed the Ph.D. qualifying examination within the past year, or
2. has a written commitment from a regular member of the EE faculty to serve as an Engineer or Ph.D. dissertation adviser, and has a satisfactory academic record to date.

Students originally admitted only for the M.S. degree and not to the Ph.D. program may petition the EE graduate admissions committee during Autumn Quarter of their second year at Stanford for a change of status to the Ph.D. program with permission to take the Ph.D. qualifying exam in January. Requirements for the petition include a grade point average of 3.5 on Stanford courses and a written statement of support from an EE faculty member with whom the student has conducted preliminary research through directed reading (EE 390 or 391) or as part of a 300-level project course. Decisions are based on performance and the strength of the support letter. If admitted to the Ph.D. program, permission to study beyond the M.S. degree is normally granted under the same conditions as those described above for students originally admitted to the Ph.D. program. Students not admitted to the Ph.D. program are normally granted permission to continue past the M.S. degree only if there is a written commitment from a regular member of the EE faculty to serve as an Engineer dissertation supervisor. The student should file for candidacy for the Engineer degree within one quarter of receiving the M.S.

ENGINEER IN ELECTRICAL ENGINEERING

The degree of Engineer requires a minimum of 90 units of residency. Units completed at Stanford towards a master's degree in an Engineering discipline may be used towards the 90-unit residency requirement for the Engineer degree. A student who received an M.S. degree elsewhere can transfer in 45 units towards the 90-unit requirement for an Engineer's degree. A student would need to fill out the Application for Graduate Residency Credit form to be filed with the Degree Progress Office in the Registrar's Office.

Work toward the degree of Engineer in Electrical Engineering normally includes the requirements for work toward the master's degree in Electrical Engineering, including qualifications for admission.

An additional year allows time for a broader program, or a more concentrated program, or whatever arrangement may seem suitable to the candidate, the adviser, and the department. Advanced study at other universities, or in other departments at Stanford, may be allowed within the foregoing consideration. The equivalent of approximately one quarter is devoted to independent study and thesis work with faculty guidance. The thesis is often of the nature of a professional report on the solution of a design problem. The degree of Engineer differs from the Ph.D. in that it prepares for professional engineering work rather than theoretical research. The candidate may select courses that are suitable for either the degree of Engineer or the Ph.D. degree and decide later which program to pursue.

The best procedure for the applicant to follow is: (1) if now working toward the Stanford M.S. degree in Electrical Engineering, request permission to continue graduate studies beyond the master's degree, using the Graduate Program Authorization Petition form obtained from the Department of Electrical Engineering office, or (2) if not planning to receive the Stanford M.S. degree in Electrical Engineering, apply for admission to the Department of Electrical Engineering as a candidate for the degree of Engineer.

During the first quarter of work beyond the M.S. degree, formal application for admission to candidacy for the degree of Engineer is made on a form that can be obtained from the department office. The program of study is prepared by the student with the help of the thesis adviser and submitted to the academic associate for approval. The form should contain a list of all graduate courses completed at Stanford and elsewhere and all courses yet to be completed. For the most recent information, see http://ee.stanford.edu/gradhandbook/engineer.html.

DOCTOR OF PHILOSOPHY IN ELECTRICAL ENGINEERING

Admission to a graduate program does not imply that the student is a candidate for the Ph.D. degree. Advancement to candidacy requires superior academic achievement, satisfactory performance on a qualifying examination, and sponsorship by two faculty members. Enrollment in EE 391, Special Studies, is recommended as a means for getting acquainted with a faculty member who might be willing to serve as a supervisor.

Students admitted to the Ph.D. program should submit an application to take the department qualifying examination (given each Winter Quarter). Upon completion of the qualifying examination and after securing agreement by two faculty members to serve as dissertation advisers, the student should file an Application for Doctoral Candidacy. Students are expected to apply for candidacy prior to the end of their second year in the Ph.D. program. The Ph.D. in Electrical Engineering is a specialized degree, and is built on a broad base of physics, mathematics, and engineering skills. The course program is expected to reflect competency in Electrical Engineering and specialized study in other areas relevant to the student's research focus. Normally the majority of units are drawn from EE department or cognate courses, with typically 9 units from related advanced physics, mathematics, engineering, or computer science courses, depending on the area of research. Only after receiving department approval of the Application for Candidacy, does the student become a candidate for the Ph.D. degree.

Requirements may be summarized as follows. The student must complete: (1) a minimum of 135 units of residence with graduate

standing at Stanford; (2) one or more qualifying examinations given by the faculty of the Department of Electrical Engineering; (3) an approved course of study in Electrical Engineering; (4) an approved program of research and a written dissertation, based on research, which must be a contribution to knowledge; (5) an oral examination that is a defense of dissertation research and is taken near the completion of the doctoral program.

FINANCIAL ASSISTANCE

The department awards a limited number of fellowships, teaching and course assistantships, and research assistantships to incoming graduate students. Applying for financial assistance is part of the admission application.

THE HONORS COOPERATIVE PROGRAM

Many of the department's graduate students are supported by the Honors Cooperative Program (HCP), which makes it possible for academically qualified engineers and scientists in nearby companies to be part-time graduate students in Electrical Engineering while continuing nearly full-time professional employment. Prospective HCP students follow the same admission process and must meet the same admission requirements as full-time graduate students. For more information regarding the Honors Cooperative Program, see the "School of Engineering" section of this bulletin.

PH.D. MINOR IN ELECTRICAL ENGINEERING

For a minor in Electrical Engineering (EE), the student must fulfill the M.S. depth requirement, complete a total of at least 20 units of course work at the 200-plus level in electrical engineering (of which 15 units must be graded), and be approved by the department's Ph.D. Degree Committee. A grade point average (GPA) of at least 3.35 on these courses is required.

AREAS OF RESEARCH IN ELECTRICAL ENGINEERING

Candidates for advanced degrees participate in the research activities of the department as paid research assistants or as students of individual faculty members. At any one time, certain areas of research have more openings than others. A new applicant should express a second choice of research interest in the event that there are no vacancies in the primary area of interest. At present, faculty members and students are actively engaged in research in the following areas:

- Biomedical Devices and Bioimaging
- Energy: solar cells, smart grid, load control
- Environmental and Remote Sensing: sensor nets, radar systems, space
- Graphics, HCI, Computer Vision, Photography
- Web Applications, Data Management, Security/Privacy
- Systems Software: OS, compilers, languages
- Systems Hardware: architecture, VLSI, embedded systems
- Network Systems and Science: next generation Internet, wireless networks
- Communication Systems: wireless, optical, wireline
- Information Theory and Coding: image and data compression, denoising
- Control, Learning, and Optimization
- Integrated Circuit Design: MEMs, sensors, analog, RF
- Quantum Science and Engineering
- Photonic and Electronic Devices
- Fields and Waves

For additional information, see the Department of Electrical Engineering's Research page at http://ee.stanford.edu/research.php.

OVERSEAS STUDIES COURSES IN ELECTRICAL ENGINEERING

For course descriptions and additional offerings, see the listings in the *Stanford Bulletin's* ExploreCourses web site (http://explorecourses.stanford.edu) or the Bing Overseas Studies web site (http://bosp.stanford.edu). Students should consult their department or program's student services office for applicability of Overseas Studies courses to a major or minor program.

SPRING QUARTER

KYOTO

OSPKYOTO 33. Digital Systems II. 4 units, Kozyrakis, GER:DB:EngrAppSci

ELECTRICAL ENGINEERING (EE)

UNDERGRADUATE COURSES IN ELECTRICAL ENGINEERING

EE 14N. Things about Stuff
(F,Sem) Stanford Introductory Seminar. Preference to freshmen. Most engineering curricula present truncated, linear histories of technology, but the stories behind disruptive inventions such as the telegraph, telephone, wireless, television, transistor, and chip are as important as the inventions themselves. How these stories elucidate broadly applicable scientific principles. Focus is on studying consumer devices; optional projects to build devices including semiconductors made from pocket change. Students may propose topics of interest to them. GER:DB-EngrAppSci
3 units, Aut (Lee, T)

EE 20N. Hacking Stuff
(F,Sem) Stanford Introductory Seminar. Preference to freshmen. The design of a complete system by combining electrical engineering disciplines such as control theory, circuit design, microprocessors, and semiconductor devices. Based on radio-controlled toy cars, the design and construction of a robot capable of autonomously following a track. Teams compete in a race against the clock in a version of the DARPA Grand Challenge. GER:DB-EngrAppSci
3 units, Aut (Peumans, P)

EE 21N. What is Nanotechnology?
(F,Sem) Stanford Introductory Seminar. Preference to freshmen. Possibilities and impossibilities of nanotechnology. Sources include Feynman's There's Plenty of Room at the Bottom, Drexler's Engines of Creation: The Coming Era of Nanotechnology, and Crichton's Prey. Assumptions and predictions of these classic works; what nano machinery may do; scenarios of a technology that may go astray. Prerequisites: high school math, physics and chemistry. GER:DB-EngrAppSci
3 units, Aut (Wong, P)

EE 23N. Imaging: From the Atom to the Universe
(F,Sem) Stanford Introductory Seminar. Preference to freshmen. Forms of imaging including human and animal vision systems, atomic force microscope, microscope, digital camera, holography and three-dimensional imaging, telescope, synthetic aperture radar imaging, nuclear magnetic imaging, sonar and gravitational wave imaging, and the Hubble Space telescope. Physical principles and exposure to real imaging devices and systems. GER:DB-EngrAppSci
3 units, Spr (Hesselink, L)

EE 24N. Incentive Mechanisms for Societal Networks
(F,Sem) Stanford Introductory Seminar. Preference to freshmen. Examples of societal networks include: transportation networks; electricity, water, and gas networks; recycling systems. The efficient operation of such networks and their dependence on their use of technology and on human actions.
3 units, Spr (Prabhakar, B)

EE 41. Physics of Electrical Engineering
How everything from electrostatics to quantum mechanics is used in common high-technology products. Electrostatics are critical in micro-mechanical systems used in many sensors and displays, and basic EM waves are essential in all high-speed communication systems. How to propagate energy in free space. Which aspects of modern physics are needed to generate light for the operation of a DVD player or TV. Introduction to semiconductors, solid-state light bulbs, and laser pointers. Hands-on labs to connect physics to everyday experience. GER:DB-EngrAppSci
5 units, Win (Solgaard, O)

EE 60N. Man versus Nature: Coping with Disasters Using Space Technology
(F,Sem) (Same as GEOPHYS 60N) Stanford Introductory Seminar. Preference to freshman. Natural hazards, earthquakes, volcanoes, floods, hurricanes, and fires, and how they affect people and society; great disasters such as asteroid impacts that periodically obliterate many species of life. Scientific issues, political and social consequences, costs of disaster mitigation, and how scientific knowledge affects policy. How spaceborne imaging technology makes it possible to respond quickly and mitigate consequences; how it is applied to natural disasters; and remote sensing data manipulation and analysis. GER:DB-EngrAppSci
4 units, Win (Zebker, H)

EE 100. The Electrical Engineering Profession
Lectures/discussions on topics of importance to the electrical engineering professional. Continuing education, professional societies, intellectual property and patents, ethics, entrepreneurial engineering, and engineering management.
1 unit, Aut (Wong, S)

EE 101A. Circuits I
First of two-course sequence. Introduction to circuit modeling and analysis. Topics include creating the models of typical components in electronic circuits and simplifying non-linear models for restricted ranges of operation (small signal model); and using network theory to solve linear and non-linear circuits under static and dynamic operations. GER:DB-EngrAppSci
4 units, Win (Wong, S)

EE 101B. Circuits II
Second of two-course sequence. MOS large-signal and small-signal models. MOS amplifier design including DC bias, small signal performance, multistage amplifiers, frequency response, and feedback. Prerequisite: 101A. GER:DB-EngrAppSci
4 units, Aut (Howe, R), Spr (Shenoy, K)

EE 102A. Signal Processing and Linear Systems I
Concepts and mathematical tools in continuous-time signal processing and linear systems analysis, illustrated with examples from signal processing, communications, and control. Mathematical representation of signals and systems. Linearity and time-invariance. System impulse and step response. Frequency domain representations: Fourier series and Fourier transforms. Filtering and signal distortion. Time/frequency sampling and interpolation. Stability and causality in linear systems. Laplace transforms and Bode plots. Feedback and control system design. Applications include radar, ultrasound imaging, fetal heart monitors, cell telephones, magnetic resonance imaging, and array antennas. Prerequisite: MATH 53 or ENGR 155A. GER:DB-EngrAppSci
4 units, Win (Pauly, J), Spr (Gray, R)

EE 102B. Signal Processing and Linear Systems II
Concepts and mathematical tools in discrete-time signal processing and linear systems analysis with examples from digital signal processing, communications, and control. Discrete-time signal models. Continuous-discrete-continuous signal conversion. Discrete-time impulse and step response. Frequency domain representations: Fourier series and transforms. Connection between continuous and discrete time frequency representations. Discrete Fourier transform (DFT) and fast Fourier transform (FFT). Digital filter and signal processing examples. Discrete-time and hybrid linear systems. Stability and causality. Z transforms and their connection to Laplace transforms. Frequency response of discrete-time systems. Discrete-time control. Prerequisite: 102A. GER:DB-EngrAppSci
4 units, Aut (Shultz, K), Spr (Kahn, J), Sum (Shultz, K)

EE 106. Planetary Exploration
The other worlds of the solar system as revealed by their electromagnetic emissions and recent space missions. Comparative properties of the terrestrial and Jovian planets; planetary atmospheres, surfaces, interiors, and rings; planetary and satellite orbits and spacecraft trajectories; properties of interplanetary gas, dust, comets, and meteorites. Blackbody radiation and the basis for global warming. What the planets reveal about potential terrestrial catastrophes such as runaway greenhouse effect or collision with an asteroid or large comet. Origin and evolution of planetary systems. Remote sensing from spacecraft at radio, infrared, light, and ultraviolet wavelengths. Stanford EE department radio experiments. Prerequisite: one year of college engineering. GER:DB-EngrAppSci
3 units, not given this year

EE 108A. Digital Systems I
Digital circuit, logic, and system design. Digital representation of information. CMOS logic circuits. Combinational logic design. Logic building blocks, idioms, and structured design. Sequential logic design and timing analysis. Clocks and synchronization. Finite state machines. Microcode control. Digital system design. Control and datapath partitioning. Lab. Prerequisite: ENGR 40. Corequisite for WIM: ENGR 102E. GER:DB-EngrAppSci
3-4 units, Aut (Mitra, S), Win (Mitra, S)

EE 108B. Digital Systems II
The design of processor-based digital systems. Instruction sets, addressing modes, data types. Assembly language programming, low-level data structures, introduction to operating systems and compilers. Processor microarchitecture, microprogramming, pipelining. Memory systems and caches. Input/output, interrupts, buses and DMA. System design implementation alternatives, software/hardware tradeoffs. Labs involve the design of processor subsystems and processor-based embedded systems. Prerequisite: 108A, CS 106B. GER:DB-EngrAppSci
3-4 units, Aut (Olukotun, O), Win (Kozyrakis, C)

EE 109. Digital Systems Design Lab
The design of integrated digital systems encompassing both customized software and hardware. Software/hardware design tradeoffs. Algorithm design for pipelining and parallelism. System latency and throughput tradeoffs. FPGA optimization techniques. Integration with external systems and smart devices. Firmware configuration and embedded system considerations. Enrollment limited to 25; preference to graduating seniors. Prerequisites: 108B, and CS 106B or X. GER:DB-EngrAppSci
4 units, Spr (Weaver, J)

EE 114. Fundamentals of Analog Integrated Circuit Design
Analysis and simulation of elementary transistor stages, current mirrors, supply- and temperature-independent bias, and reference circuits. Integrated circuit technologies, circuit components, component variations, and practical design paradigms. Performance evaluation using computer-aided design tools. Prerequisite: 101B.GER:DB-EngrAppSci GER:DB-EngrAppSci
3 units, Aut (Dutton, R)

EE 116. Semiconductor Device Physics
The fundamental operation of semiconductor devices and overview of applications. The physical principles of semiconductors, both silicon and compound materials; operating principles and device equations for junction devices (diodes, bipolar transistor, photodetectors). Introduction to quantum effects and band theory of solids. Prerequisite: ENGR 40. Corequisite: 101B. GER:DB-EngrAppSci
3 units, Spr (Peumans, P)

EE 118. Introduction to Mechatronics
Technologies involved in mechatronics (intelligent electromechanical systems) and techniques to integrate these technologies into mechatronic systems. Topics: electronics (A/D, D/A converters, op-amps, filters, power devices); software program design (event-driven programming, state machine based design); DC and stepper motors; basic sensing; mechanical design (machine elements and mechanical CAD). Lab component of structured assignments combined with large, open-ended team project. Limited enrollment. Prerequisites: ENGR 40, and CS 106A or 106X (preferred).
4 units, not given this year

EE 122A. Analog Circuits Laboratory
Practical applications of analog circuits, including simple amplifiers, filters, oscillators, power supplies, and sensors. Design skills, computer-aided design, and circuit fabrication and debugging. The design process through proposing, designing, simulating, building, debugging, and demonstrating a project. Radio frequency and largely digital projects not suitable for EE 122. Prerequisite: ENGR 40 or equivalent. GER:DB-EngrAppSci
  3 units, Aut (Giovangrandi, L)

EE 122B. Introduction to Biomedical Electronics
Key components of modern systems, their application in physiology measurements, and reduction to practice in labs. Fundamentals of analog/digital conversion and filtering techniques for biosignals, typical transducers (biopotential, electrochemical, temperature, pressure, acoustic, movement), and interfacing circuits. Issues of biomedical electronics (safety, isolation, noise). Prerequisite: EE122A
  3 units, Spr (Giovangrandi, L)

EE 124. Introduction to Neuroelectrical Engineering
Fundamental properties of electrical activity in neurons, technology for measuring and altering neural activity, and operating principles of modern neurological and neural prosthetic medical systems. Topics: action potential generation and propagation, neuro-MEMS and measurement systems, experimental design and statistical data analysis, information encoding and decoding, clinical diagnostic systems, and fully-implantable neural prosthetic systems design.
  3 units, Win (Shenoy, K)

EE 133. Analog Communications Design Laboratory
Design, testing, and applications. Amplitude modulation (AM) using multiplier circuits. Frequency modulation (FM) based on discrete oscillator and integrated modulator circuits such as voltage-controlled oscillators (VCOs). Phased-lock loop (PLL) techniques, characterization of key parameters, and their applications. Practical aspects of circuit implementations. Labs involve building and characterization of AM and FM modulation/demodulation circuits and subsystems. Enrollment limited to 30 undergraduates and coterminal EE students. Prerequisite: 101B. GER:DB-EngrAppSci
  4 units, Win (Dutton, R)

EE 134. Introduction to Photonics
Photonics, optical sensors, and fiber optics. Conceptual and mathematical tools for design and analysis of optical communication and sensor systems. Experimental characterization of semiconductor lasers, optical fibers, photodetectors, receiver circuitry, fiber optic links, optical amplifiers, and optical sensors. Class project aimed on confocal microscopy for biomedical applications. Laboratory experiments. Prerequisite: 41 or equivalent. GER:DB-EngrAppSci
  4 units, Spr (Solgaard, O)

EE 136. Introduction to Nanophotonics and Nanostructures
Electromagnetic and quantum mechanical waves and semiconductors. Confining these waves, and devices employing such confinement. Localization of light and applications: metallic mirrors, photonic crystals, optical waveguides, microresonators, plasmonics. Localization of quantum mechanical waves: quantum wells, wires, and dots. Generation of light in semiconductors: spontaneous and stimulated emission, lasers, and light emitting diodes. Devices incorporating localization of both electromagnetic and quantum mechanical waves such as resonant cavity quantum well lasers and microcavity-based single photon sources. System-level applications such as optical communications, biochemical sensing, and quantum cryptography. Prerequisite: familiarity with electromagnetic and quantum mechanical waves and semiconductors at the level of EE 41 or equivalent. GER:DB-EngrAppSci
  3 units, Aut (Vuckovic, J)

EE 140. The Earth From Space: Introduction to Remote Sensing
(Same as GEOPHYS 140) Global change science as viewed using space remote sensing technology. Global warming, ozone depletion, the hydrologic and carbon cycles, topographic mapping, and surface deformation. Physical concepts in remote sensing. EM waves and geophysical information. Sensors studied: optical, near and thermal IR, active and passive microwave. GER:DB-EngrAppSci
  3 units, not given this year

EE 141. Engineering Electromagnetics
Lumped versus distributed circuits. Transient response of transmission lines with resistive and reactive loads. Reflection, transmission, attenuation and dispersion. Steady-state waves on transmission lines. Standing wave ratio, impedance matching, and power flow. Coulomb's law, electrostatic field, potential and gradient, electric flux and Gauss's Law and divergence. Metallic conductors, Poisson's and Laplace's equations, capacitance, dielectric materials. Electrostatic energy and forces. Steady electric currents, Ohm's Law, Kirchoff's Laws, charge conservation and the continuity equation, Joule's Law. Biot-Savart's law and the static magnetic field. Ampere's Law and curl. Vector magnetic potential and magnetic dipole. Magnetic materials, forces and torques. Faraday's Law, magnetic energy, displacement current and Maxwell's equations. Uniform plane waves. Prerequisites: 102A, MATH 52. GER:DB-EngrAppSci
  3 units, Aut (Harris, S)

EE 168. Introduction to Digital Image Processing
Computer processing of digital 2-D and 3-D data, combining theoretical material with implementation of computer algorithms. Topics: properties of digital images, design of display systems and algorithms, time and frequency representations, filters, image formation and enhancement, imaging systems, perspective, morphing, and animation applications. Instructional computer lab exercises implement practical algorithms. Final project consists of computer animations incorporating techniques learned in class. Prerequisite: Matlab programming. GER:DB-EngrAppSci
  3-4 units, not given this year

EE 178. Probabilistic Systems Analysis
Introduction to probability and statistics and their role in modeling and analyzing real world phenomena. Events, sample space, and probability. Discrete random variables, probability mass functions, independence and conditional probability, expectation and conditional expectation. Continuous random variables, probability density functions, independence and expectation, derived densities. Transforms, moments, sums of independent random variables. Simple random processes. Limit theorems. Introduction to statistics: significance, hypothesis testing, estimation and detection, Bayesian analysis. Prerequisites: basic calculus and linear algebra. GER:DB-EngrAppSci
  3 units, Win (Gray, R)

EE 179. Introduction to Communications
Communication system design and performance analysis. Topics include current communication systems (cellular, WLANs, radio and TV broadcasting, satellites, Internet), Fourier techniques, energy and power spectral density, random variables and random (noise) signals, filtering and modulation of noise, analog modulation (AM and FM) and its performance in noise, digital modulation (PSK and FSK), optimal receiver design, and probability of bit error for digital modulation. Prerequisite: 102A. GER:DB-EngrAppSci
  3 units, Spr (Goldsmith, A)

EE 190. Special Studies or Projects in Electrical Engineering
Independent work under the direction of a faculty member. Individual or team activities involve lab experimentation, design of devices or systems, or directed reading.
  1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EE 191. Special Studies and Reports in Electrical Engineering
Independent work under the direction of a faculty member given for a letter grade only. If a letter grade given on the basis of required written report or examination is not appropriate, enroll in 190.
  1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EE 192C. Embedded Systems Engineering
From problem statement to final fabrication at the system level. Topics include: microprocessor architecture review; communication protocols (I2C, SPI EIA/TIA232, 422,485, CAN, OneWire); peripheral devices (timers, ADCs, DACs, human-computer interface); solid state storage (CF, MMC); OrCAD design tools; hardware-software interactions and design considerations; and real time operating systems (ROTS). Final design project from concept to PCB layout and firmware development.
3 units, not given this year

GRADUATE COURSES IN ELECTRICAL ENGINEERING

EE 203. The Entrepreneurial Engineer
Seminar. For prospective entrepreneurs with an engineering background. Contributions made to the business world by engineering graduates. Speakers include Stanford and other engineering and M.B.A. graduates who have founded large and small companies in nearby communities. Contributions from EE faculty and other departments including Law, Business, and MS&E.
1 unit, Win (Melen, R)

EE 204. Business Management for Electrical Engineers and Computer Scientists
For graduate students with little or no business experience. Leading computer, high-tech, and Silicon Valley companies and their best practices. Tools and frameworks for analyzing decisions these companies face. Corporate strategy, new product development, marketing, sales, distribution, customer service, financial accounting, outsourcing, and human behavior in business organizations. Case studies. Prerequisite: graduate standing.
3 units, Spr (Gibbons, F)

EE 212. Integrated Circuit Fabrication Processes
For students interested in the physical bases and practical methods of silicon VLSI chip fabrication, or the impact of technology on device and circuit design, or intending to pursue doctoral research involving the use of Stanford's Nanofabrication laboratory. Process simulators illustrate concepts and provide a virtual lab experience. Topics: principles of integrated circuit fabrication processes, physical and chemical models for crystal growth, oxidation, ion implantation, etching, deposition, lithography, and back-end processing. Required for 410.
3 units, Aut (Plummer, J)

EE 214. Advanced Analog Integrated Circuit Design
Analysis and design of analog integrated circuits in advanced MOS and bipolar technologies. Device operation and compact modeling in support of circuit simulations needed for design. Emphasis is on quantitative evaluations of performance using hand calculations and circuit simulations; intuitive approaches to design. Analytical and approximate treatments of noise and distortion; analysis and design of feedback circuits. Design of archetypal analog blocks for networking and communications such as broadband gain stages and transimpedance amplifiers. Prerequisite: EE 114.
3 units, Win (Murmann, B)

EE 216. Principles and Models of Semiconductor Devices
Carrier generation, transport, recombination, and storage in semiconductors. Physical principles of operation of the p-n junction, heterojunction, metal semiconductor contact, bipolar junction transistor, MOS capacitor, MOS and junction field-effect transistors, and related optoelectronic devices such as CCDs, solar cells, LEDs, and detectors. First-order device models that reflect physical principles and are useful for integrated-circuit analysis and design. Prerequisite: 116 or equivalent.
3 units, Aut (Staff), Win (Saraswat, K; Howe, R)

EE 216S. Principles and Models of Semiconductor Devices
For advanced undergraduates and graduate students. The fundamentals of carrier transport and recombination generation in semiconductors. The physical principles of the operation of the p-n junctions, metal-semiconductor contacts, MOS capacitors, MOS-FETs. Overview of BJTs and photonic devices such as LEDs, lasers, photodiodes, solar cells. Prerequisite: EE 116 or equivalent
2 units, Sum (Janjua, A)

EE 222. Applied Quantum Mechanics I
Emphasis is on applications in modern devices and systems. Topics include: Schrödinger's equation, eigenfunctions and eigenvalues, operator approach to quantum mechanics, Dirac notation, solutions of simple problems including quantum wells and tunneling. Quantum harmonic oscillator, coherent states. Calculation techniques including matrix diagonalization, perturbation theory, and variational method. Time-dependent perturbation theory, applications to optical absorption, nonlinear optical coefficients, and Fermi's golden rule. Quantum mechanics in crystalline materials. Prerequisites: MATH 52 and 53, PHYSICS 65 (or PHYSICS 43 and 45).
3 units, Aut (Miller, D)

EE 223. Applied Quantum Mechanics II
Continuation of 222, including more advanced topics: angular momentum in quantum mechanics, spin, hydrogen atom, systems of identical particles (bosons and fermions), methods for one-dimensional problems, introductory quantum optics (electromagnetic field quantization, coherent states), fermion annihilation and creation operators, interaction of different kinds of particles (spontaneous emission, optical absorption, and stimulated emission). Quantum information and interpretation of quantum mechanics. Other topics in electronics, optoelectronics, optics, and quantum information science. Prerequisite: 222.
3 units, Win (Miller, D)

EE 228. Basic Physics for Solid State Electronics
Topics: energy band theory of solids, energy bandgap engineering, classical kinetic theory, statistical mechanics, and equilibrium and non-equilibrium semiconductor statistics. Prerequisite: course in modern physics.
3 units, Aut (Fan, S)

EE 231. Introduction to Lasers
How lasers work, including quantum transitions in atoms, stimulated emission and amplification, rate equations, saturation, feedback, coherent optical oscillation, laser resonators, and optical beams. Limited primarily to steady-state behavior; classical models for atomic transitions with little quantum mechanics background required. Prerequisites: electromagnetic theory to the level of 142, preferably 241, and some atomic or modern physics such as PHYSICS 70 or 130, 131.
3 units, Win (Digonnet, M)

EE 232. Laser Dynamics
Continuation of 231, emphasizing dynamic and transient effects including spiking, Q-switching, mode locking, frequency modulation, frequency and spatial mode competition, linear and nonlinear pulse propagation, short pulse expansion, and compression. Prerequisite: 231.
3 units, Spr (Fan, S)

EE 233. Analog Design Communications Laboratory
Design, testing, and applications. Amplitude modulation (AM) using multiplier circuits. Frequency modulation (FM) based on discrete oscillator and integrated modulator circuits such as voltage-controlled oscillators (VCOs). Phased-lock loop (PLL) techniques, characterization of key parameters, and their applications. Practical aspects of circuit implementations. Labs involve building and characterization of AM and FM modulation/demodulation circuits and subsystems. Enrollment limited to 30 undergraduates and coterminal EE students. Prerequisite: 101B. Recommended: 122
3 units, Win (Dutton, R)

EE 234. Photonics Laboratory
Photonics and fiber optics with a focus on communication and sensing. Experimental characterization of semiconductor lasers, optical fibers, photodetectors, receiver circuitry, fiber optic links, optical amplifiers, and optical sensors and photonic crystals. Prerequisite: EE 142.
3 units, Win (Vuckovic, J)

EE 235. Guided Wave Optical Devices

Guided wave optics, optical waveguide devices, and integrated optics. Wave propagation in layered media, slab waveguides, and optical fibers. Rectangular waveguides. Optical waveguide technology. Coupled-mode theory. Numerical analysis of complex waveguides. Photonic crystals. Physics and design of waveguide devices. Fiber sensors, waveguide gratings, waveguide modulators, directional couplers, ring filters. Prerequisite: electromagnetic theory to the level of 142 or equivalent.

3 units, not given this year

EE 237. Solar Energy Conversion

Basics of solar energy conversion in photovoltaic devices and solar thermal systems. Solar cell device physics: electrical and optical. Solar system issues including module assembly, inverters, and micro-inverters. Concentrated solar power. Students design solar cells. Prerequisite: EE 116 or EE 216.

3 units, Win (Staff)

EE 242. Electromagnetic Waves

Continuation of 141. Maxwell's equations. Plane waves in lossless and lossy media. Skin effect. Flow of electromagnetic power. Poynting's theorem. Reflection and refraction of waves at planar boundaries. Snell's law and total internal reflection. Reflection and refraction from lossy media. Guided waves. Parallel-plate and dielectric-slab waveguides. Hollow wave-guides, cavity resonators, microstrip waveguides, optical fibers. Interaction of fields with matter and particles. Antennas and radiation of electromagnetic energy. Prerequisite: 141 or PHYSICS 120.

3 units, Win (Fraser-Smith, A)

EE 243. Semiconductor Optoelectronic Devices

Semiconductor physics and optical processes in semiconductors. Operating principles and practical device features of semiconductor optoelectronic materials and heterostructures. Devices include: optical detectors (p-i-n, avalanche, and MSM); light emitting diodes; electroabsorptive modulators (Franz-Keldysh and QCSE), electrorefractive (directional couplers, Mach-Zehnder), switches (SEEDs); and lasers (waveguide and vertical cavity surface emitting). Prerequisites: semiconductor devices and solid state physics such as EE 216 and 228 or equivalents. Recommended: basic quantum mechanics and lasers such as EE 216 and 231 or equivalents.

3 units, Win (Harris, J)

EE 247. Introduction to Optical Fiber Communications

Fibers: single- and multi-mode, attenuation, modal dispersion, group-velocity dispersion, polarization-mode dispersion. Nonlinear effects in fibers: Raman, Brillouin, Kerr. Self- and cross-phase modulation, four-wave mixing. Sources: light-emitting diodes, laser diodes, transverse and longitudinal mode control, modulation, chirp, linewidth, intensity noise. Modulators: electro-optic, electro-absorption. Photodiodes: p-i-n, avalanche, responsivity, capacitance, transit time. Receivers: high-impedance, transimpedance, bandwidth, noise. Digital intensity modulation formats: non-return-to-zero, return-to-zero. Receiver performance: Q factor, bit-error ratio, sensitivity, quantum limit. Sensitivity degradations: extinction ratio, intensity noise, jitter, dispersion. Wavelength-division multiplexing. System architectures: local-area, access, metropolitan-area, long-haul. Prerequisites: 102A or 261, and 242 or 235 or 241, and 178 or 179.

3 units, Aut (Kahn, J)

EE 248. Fundamentals of Noise Processes

Mathematical methods and physical principles: statistics, Fourier analysis, statistical and quantum mechanics. Circuit theory: thermal noise, quantum noise, fluctuation-dissipation theorem. Macroscopic and mesoscopic conductors. Macroscopic and mesoscopic p-n junctions. 1/f noise and random telegraphic noise. Negative conductance oscillators (lasers) and nonlinear susceptance oscillators (optical parametric amplifier). Optical and quantum communication systems. Weak force detection systems. Prerequisites: elementary device, circuit, and electromagnetic waves to the level of 101A,B and 242.

3 units, not given this year

EE 249. Introduction to the Space Environment

The environment through which space probes and vehicles travel and orbit, and which moderates solar gases and radiation. Experimentation in this environment, tools used; regions into which it is divided including ionosphere, magnetosphere, heliosphere, and interplanetary space. The role of the Sun, the effects of changes in solar activity, charged particle motion which in combination with the Earth's magnetic field leads to auroras and the Van Allen belts. Prerequisites: electromagnetics at the level of 242 and senior or graduate standing.

3 units, not given this year

EE 252. Antennas for Telecommunications and Remote Sensing

Fundamental properties. Dipoles, loops, reflectors, Yagis, helices, slots, horns, micro-strips. Antennas as transitions between guided and free radiation, ultrasound analogue. Famous antennas. Pattern measurements. Friis and radar equations. Feeds, matching, baluns. Broadbanding. Arrays, aperture synthesis, interferometry, very-long-baseline interferometry. Thermal radiation, antenna temperature, microwave passive remote sensing. Prerequisite: 242 or equivalent.

3 units, not given this year

EE 256. Numerical Electromagnetics

Principles and applications of numerical techniques for solving practical electromagnetics problems. Time domain solutions of Maxwell's equations. Finite difference time domain (FDTD) methods. Numerical stability, dispersion, and dissipation. Absorbing boundary conditions. Perfectly matched layer methods. Explicit and implicit methods. FDTD modeling of propagation and scattering in dispersive and anisotropic media. Near-to-far-zone transformations. Computational problems require programming and use of MATLAB and other tools. Prerequisite: 242 or equivalent.

3 units, not given this year

EE 261. The Fourier Transform and Its Applications

The Fourier transform as a tool for solving physical problems. Fourier series, the Fourier transform of continuous and discrete signals and its properties. The Dirac delta, distributions, and generalized transforms. Convolutions and correlations and applications; probability distributions, sampling theory, filters, and analysis of linear systems. The discrete Fourier transform and the FFT algorithm. Multidimensional Fourier transform and use in imaging. Further applications to optics, crystallography. Emphasis is on relating the theoretical principles to solving practical engineering and science problems. Prerequisites: Fourier series at the level of 102A, and linear algebra.

3 units, Aut (Osgood, B), Win (Nishimura, D), Sum (Bhatnagar, R)

EE 262. Two-Dimensional Imaging

Time and frequency representations, two-dimensional auto- and cross-correlation, Fourier spectra, diffraction and antennas, coordinate systems and the Hankel and Abel transforms, line integrals, impulses and sampling, restoration in the presence of noise, reconstruction and tomography, imaging radar. Tomographic reconstruction using projection-slice and layergram methods. Students create software to form images using these techniques with actual data. Final project consists of design and simulation of an advanced imaging system. Prerequisite: 261. Recommended: 278, 279.

3 units, Win (Zebker, H)

EE 263. Introduction to Linear Dynamical Systems

Applied linear algebra and linear dynamical systems with application to circuits, signal processing, communications, and control systems. Topics: least-squares approximations of over-determined equations and least-norm solutions of underdetermined equations. Symmetric matrices, matrix norm, and singular value decomposition. Eigenvalues, left and right eigenvectors, with dynamical interpretation. Matrix exponential, stability, and asymptotic behavior. Multi-input/multi-output systems, impulse and step matrices; convolution and transfer matrix descriptions. Control, reachability, and state transfer; observability and least-squares state estimation. Prerequisites: linear algebra and matrices as in MATH 103; differential equations and Laplace transforms as in EE 102A.

3 units, Aut (Lall, S)

EE 264. Digital Signal Processing
Two sided Z-transform. Linear time invariant discrete time systems. Sampling theory; A/D and D/A conversion. Analog and digital filter design. Quantization of signals and filter coefficients. Signal scaling. DFS, DFT, and sampling in the frequency domain. Interpolation and decimation. Oversampling techniques for ADC and DAC. Digital signal processing for wireless communications. Prerequisite: 102B. Recommended: 261, 278.
 3 units, Aut (Schafer, R), Sum (Aragon, J)

EE 265. Digital Signal Processing Laboratory
Applying 102A,B to real-world signal processing applications. Lab exercises use a programmable DSP to implement signal processing tasks. Topics: A/D conversion and quantization, sampling theorem, Z-transform, discrete-time Fourier transform, digital filter design and implementation, spectral analysis, rate conversion, wireless data communication, and OFDM receiver design. Prerequisites: 102A,B. Recommended: 261.
 3-4 units, Win (Meng, T)

EE 268. Introduction to Modern Optics
Geometrical optics: ray matrices, Gaussian beams, optical instruments, and radiometry. Wave nature of light: Maxwell's equations, propagation through media with varying index of refraction (e.g., fibers). Interferometry: basic principles, practical systems, and applications.
 3 units, Aut (Byer, R)

EE 271. Introduction to VLSI Systems
Large-scale MOS design. Topics: MOS transistors, static and dynamic MOS gates, MOS circuit fabrication, design rules, resistance and capacitance extraction, power and delay estimation, scaling, MOS combinational and sequential logic design, registers and clocking schemes, memory, data-path, and control-unit design. Elements of computer-aided circuit analysis, synthesis, and layout techniques. Prerequisites: 101A and 108B; familiarity with transistors, logic design, Verilog, and digital system organization.
 3 units, Aut (Horowitz, M)

EE 273. Digital Systems Engineering
Electrical issues in the design of high-performance digital systems, including signaling, timing, synchronization, noise, and power distribution. High-speed signaling methods; noise in digital systems, its effect on signaling, and methods for noise reduction; timing conventions; timing noise (skew and jitter), its effect on systems, and methods for mitigating timing noise; synchronization issues and synchronizer design; clock and power distribution problems and techniques; impact of electrical issues on system architecture and design. Prerequisites: 102B and 108A, or equivalents. Recommended: 214.
 3 units, Win (Weaver, J)

EE 276. Introduction to Wireless Personal Communications
Frequency reuse, cellular concepts, cochannel interference, handoff. Radio propagation in and around buildings: Friis equation, multipath, narrow-band and wide-band channels, small scale and large-scale statistics, space and time signal variation. Diversity. Receiver sensitivity, sources of noise, range. Performance statistics: coverage, margin, digital modulation, adjacent channel interference, and digital error rates. Wide band channels: maximum transmission rates. Multi-server queuing and traffic: Erlang formulas. Multiple access, FDMA, TDMA, CDMA; duplexing, FDD and TDD; multipath mitigation, OFDM, equalization, spread spectrum. Prerequisites: 242 and 278 or equivalent. Corequisite: 279 or equivalent.
 3 units, Spr (Cox, D)

EE 278. Introduction to Statistical Signal Processing
Random variables, vectors, and processes; convergence and limit theorems; IID, independent increment, Markov, and Gaussian random processes; stationary random processes; autocorrelation and power spectral density; mean square error estimation, detection, and linear estimation. Prerequisites: 178 or STATS 116, and linear systems and Fourier transforms at the level of 102A,B or 261.
 3 units, Aut (Prabhakar, B), Spr (Gill, J), Sum (Su, H)

EE 279. Introduction to Communication Systems
Analysis and design of communication systems; analog and digital modulation and demodulation, frequency conversion, multiplexing, noise and distortion; spectral and signal-to-noise ratio analy-
sis, probability of error in digital systems, spread spectrum. Prerequisites: 179 or 261, and 178 or 278.
 3 units, Win (Cox, D)

EE 282. Computer Systems Architecture
Advanced system-level architecture techniques for devices such as personal computers, servers, and embedded or portable systems. Topics such as cache hierarchies, memory systems, storage and IO systems, virtualization, clusters, fault-tolerance, and low-power design. Interactions between hardware and software layers in such systems. Performance analysis and optimization techniques for small- and large-scale systems. Principles such as locality, coarse-grain parallelism, overlapping communication and computation, performance/power trade-offs, and reliability. Prerequisite: 108B. Recommended: CS 140.
 3 units, Spr (Kozyrakis, C)

EE 284. Introduction to Computer Networks
Structure and components of computer networks; functions and services; packet switching; layered architectures; OSI reference model; physical layer; data link layer; error control; window flow control; media access control protocols used in local area networks (Ethernet, Token Ring, FDDI) and satellite networks; network layer (datagram service, virtual circuit service, routing, congestion control, Internet Protocol); transport layer (UDP, TCP); application layer.
 3 units, Aut (Medapalli, K)

EE 290A. Curricular Practical Training for Electrical Engineers
For EE majors who need work experience as part of their program of study. Final report required. Prerequisites: for 290B, candidacy for Engineer or Ph.D. in Electrical Engineering; for 290C, candidacy for Ph.D. degree in Electrical Engineering; for 290D, consent of instructor.
 1 unit, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EE 290B. Curricular Practical Training for Electrical Engineers
For EE majors who need work experience as part of their program of study. Final report required. Prerequisites: for 290B, candidacy for Engineer or Ph.D. in Electrical Engineering; for 290C, candidacy for Ph.D. degree in Electrical Engineering; for 290D, consent of instructor.
 1 unit, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EE 290C. Curricular Practical Training for Electrical Engineers
For EE majors who need work experience as part of their program of study. Final report required. Prerequisites: for 290B, candidacy for Engineer or Ph.D. in Electrical Engineering; for 290C, candidacy for Ph.D. degree in Electrical Engineering; for 290D, consent of instructor.
 1 unit, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EE 290D. Curricular Practical Training for Electrical Engineers
For EE majors who need work experience as part of their program of study. Final report required. Prerequisites: for 290B, candidacy for Engineer or Ph.D. in Electrical Engineering; for 290C, candidacy for Ph.D. degree in Electrical Engineering; for 290D, consent of instructor.
 1 unit, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EE 292E. Analysis and Control of Markov Chains
Finite-state and countable-state Markov chains. Controlled Markov chains and dynamic programming algorithms. Application to modeling and analysis of engineering systems. Prerequisites: 263, 278.
 3 units, not given this year

EE 292G. Power Electronics
Power conversion fundamentals including linear/shunt regulators, charge pumps, Buck, Boost, Buck-Boost, SEPIC, Cuk, and Flyback converters, magnetic components, volt second balance, continuous/discontinuous mode, synchronous/non-synchronous operation, voltage/current mode control, fixed frequency PWM and constant on or off time control, control loop analysis, compensator design, RMS/average value calculations for PWM current waveforms, inductor, capacitor, and MOSFET parasitics, output ripple, transient response, gate drive strategies, efficiency prediction, soft start, current limit, efficiency and power loss plots.
 3 units, Aut (Staff)

EE 293A. Fundamentals of Energy Processes
For seniors and graduate students. Thermodynamics, heat engines, thermoelectics, biomass. Recommended: MATH 41, 43; PHYSICS 41, 43, 45
3-4 units, Aut (da Rosa, A)

EE 293B. Fundamentals of Energy Processes
For seniors and graduate students. Fuel cells. Production of hydrogen: electrolytic, chemical, thermolytic, photolytic. Hydrogen storage: hydrides. Photoelectric converters; photo-thermovoltaic converters. Wind turbines. Recommended: EE 293A; MATH 41; PHYSICS 41, 43, 45
3-4 units, Win (da Rosa, A)

EE 300. Master's Thesis and Thesis Research
Independent work under the direction of a department faculty. Written thesis required for final letter grade. The continuing grade 'N' is given in quarters prior to thesis submission. See 390 if a letter grade is not appropriate.
1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EE 302. Biomedical Electronics
Biomedical electronics and instruments based on electrical engineering for diagnostics and therapeutic treatments of biological systems, focusing on the theory and design principles in modern biomedical electronics using electromagnetic properties. Topics include circuit design for implanted medical devices, physics and signal processing for medical imaging systems, techniques for neural measurements and neuro-decoding, and electronics for drug delivery. Prerequisites: EE 214, 264, and 265.
3 units, Win (Poon, A)

EE 303. Autonomous Implantable Systems
How implantable systems can revolutionize health care in the coming decades. Potential applications include implantable sensors and monitoring devices for preventive and post-surgery monitoring; drug delivery systems that can be placed closer to cancer cells and are able to administer dosage automatically; medical robots that perform surgery inside patients with greater precision and less pain; and neural implants for brain-machine interface. Focus is on the analysis and design of remotely-powered, miniature implantable devices for those applications.
3 units, Spr (Poon, A)

EE 309. Semiconductor Memory Devices and Technology
Memory devices: SRAM, DRAM, NVRAM (non-volatile memory). Functionality and performance of ULSI systems. Semiconductor memories, device design considerations, device scaling, device fabrication, addressing, and readout circuits. Cell structures (1T-1C, 6T, 4T, 1T-1R, 0T-1R, floating gate FLASH, SONOS, NROM), and memory organization (open bit-line, folded bit-line, NAND, NOR, cross-point). New memory concepts such as nano-crystal memory, single-electron memory, magnetic tunnel junction memory (MRAM), ferroelectric memory (FRAM), phase change memory (PRAM), T-RAM, polymer memory, metal oxide memory, nanoconductive bridge memory). Prerequisite: 216. Recommended: 212, 311, 316.
3 units, Aut (Wong, P)

EE 310. Integrated Circuits Technology and Design Seminar
State-of-the-art micro- and nanoelectronics, nanotechnology, advanced materials, and nanoscience for device applications. Prerequisites: 216, 316.
1 unit, Win (Nishi, Y; Wong, P; Saraswat, K)

EE 311. Advanced Integrated Circuits Technology
Practical and fundamental limits to the evolution of the technology of modern MOS devices. Modern device and circuit fabrication and likely future changes. Advanced techniques and models of device and back-end (interconnect and contact) processing. Use of TSUPREM4 and MEDICI for process and device modeling. MOS process integration. Prerequisites: 212, 216.
3 units, Spr (Saraswat, K)

EE 312. Micromachined Sensors and Actuators
Solid-state sensors and actuators, focusing on the use of integrated circuit fabrication technology for their realization. Categories of sensors and actuators include biological, chemical, mechanical, optical, and thermal. Mechanisms of transduction, fabrication techniques, and relative merits of different technologies. Micromachining techniques for monolithic integration of active circuits with sensors or actuators. Directions for future research. Prerequisite: 212 or equivalent.
3 units, Win (Giovangrandi, L)

EE 313. Digital MOS Integrated Circuits
Analysis and design of digital MOS integrated circuits. Development of different models for MOS transistors and how to use them to analyze circuit performance. Use of computer-aided circuit analysis. Logic styles include static, dynamic and pass logic, pulse-mode gates, and current-mode logic. Topics include sizing for min delay, noise and noise margins, power dissipation. The class uses memory design (SRAM) as a motivating example. DRAM and EEPROM design issues. Prerequisites: 101B, 108A. Recommended: 271.
3 units, Win (Kim, J)

EE 314. RF Integrated Circuit Design
Design of RF integrated circuits for communications systems, primarily in CMOS. Topics: the design of matching networks and low-noise amplifiers at RF, passive and active filters, mixers, modulators, and demodulators; review of classical control concepts necessary for oscillator design including PLLs and PLL-based frequency synthesizers. Design of low phase noise oscillators. Design of high-efficiency (e.g., class E, F) RF power amplifiers, coupling networks. Behavior and modeling of passive and active components at RF. Narrowband and broadband amplifiers; noise and distortion measures and mitigation methods. Overview of transceiver architectures. Prerequisite: 214.
3 units, Spr (Lee, T)

EE 315A. VLSI Signal Conditioning Circuits
Design and analysis of integrated circuits for active filters, precision gain stages, and sensor interfaces in CMOS VLSI technology. Operational transconductance amplifiers; sampled-data and continuous-time analog filters. Analysis of noise and amplifier imperfections; compensation techniques such as correlated double sampling. Sensor interfaces for micro-electromechanical and biomedical applications. Layout techniques for analog integrated circuits.
3 units, Spr (Murmann, B)

EE 315B. VLSI Data Conversion Circuits
Architectural and circuit level design and analysis of integrated analog-to-digital and digital-to-analog interfaces in CMOS VLSI technology. Circuit elements such as sample-and-hold circuits and voltage comparators. Circuits and architectures for Nyquist-rate and oversampling analog-to-digital and digital-to-analog conversion; digital decimation and interpolation filters. Examples of calibration and digital enhancement techniques. Prerequisite:EE 214. Recommended: EE 315A.
3 units, Aut (Murmann, B)

EE 316. Advanced VLSI Devices
In modern VLSI technologies, device electrical characteristics are sensitive to structural details and therefore to fabrication techniques. How are advanced VLSI devices designed and what future changes are likely? What are the implications for device electrical performance caused by fabrication techniques? Physical models for nanometer scale structures, control of electrical characteristics (threshold voltage, short channel effects, ballistic transport) in small structures, and alternative device structures for VLSI. Prerequisites: 212 and 216, or equivalent.
3 units, Win (Wong, P)

EE 317. Micropatterning for Integrated Circuits
The fundamentals of generating submicron patterns in integrated circuit manufacturing. Technologies include the formation of submicron images of ultraviolet light, the resulting exposure of polymeric resists, the subsequent development of resist patterns and their transfer into functional circuit material patterns through plasma etching and other techniques. Use of phase-shifting masks and other wavefront-engineering approaches. Hands-on computer simulations. Prerequisites: 141 or equivalent, 212 or equivalent.
3 units, not given this year

EE 319. Advanced Nanoelectronic Devices and Technology

Recent advances in materials science, device physics and structures, and processing technology, to extend VLS1 device scaling towards atomistic and quantum-mechanical physics boundaries. Topics include: mobility-enhancement techniques; nanomaterial structures including tube, wire, beam, and crystal; conducting polymer; 3D FET; gate-wraparound FET; nonvolatile memory phenomena and devices; self-assembly; flash annealing; plasma doping; and nano pattering. Prerequisites: 216, 316.

3 units, Spr (Nishi, Y; Sze, S)

EE 320. Nanoelectronics

Focus is on the device physics and operation principles of nanoelectric devices. Topics identified by the International Technology Roadmap for Semiconductors, emerging research devices section; see http://www.itrs.net. Non-silicon-based devices such as carbon nanotubes, grapheme, semiconductor nanowires, and molecular devices; and non-FET based devices such as single electron transistors (SET) and resonant tunneling diodes (RTD). Logic and memory devices. Prerequisites: undergraduate device physics, EE 222, 216. Recommended: EE 223, 228, or 316.

3 units, not given this year

EE 322. Molecular Electronics and Photonics

Physics of charge and energy transfer in molecular systems and connection with traditional mesoscopic transport theories. Analysis of molecular organic light-emitting diodes, photovoltaic cells and transistors. Technology and applications of molecular semiconductors. Prerequisite: 228 or equivalent.

3 units, not given this year

EE 327. Properties of Semiconductor Materials

Modern semiconductor devices and integrated circuits are based on unique energy band, carrier transport, and optical properties of semiconductor materials. How to choose these properties for operation of semiconductor devices. Emphasis is on quantum mechanical foundations of the properties of solids, energy bandgap engineering, semiclassical transport theory, semiconductor statistics, carrier scattering, electro-magneto transport effects, high field ballistic transport, Boltzmann transport equation, quantum mechanical transitions, optical absorption, and radiative and nonradiative recombination. Prerequisites: 216, 228.

3 units, not given this year

EE 328. Physics of Advanced Semiconductor Devices

Principles governing the operation of modern semiconductor devices. Assumptions and approximations commonly made in analyzing devices. Emphasis is on the application of semiconductor physics to the development of advanced semiconductor devices such as heterojunctions, HJ-bipolar transistors, HJ-FETs, nanostructures, tunneling, single electron transistor and photonic devices. Use of ATLAS, a 2-D Poisson solver, for simulation of ultrasmall devices. Examples related to state-of-the-art devices and current device research. Prerequisite: 216. Recommended: 316.

3 units, Spr (Harris, J)

EE 329. The Electronic Structure of Surfaces and Interfaces

Physical concepts and phenomena for surface science techniques probing the electronic structure of surfaces and interfaces. Microscopic and atomic models of microstructures; applications such as within semiconductor device technology and catalysis. Physical processes of low energy electron diffraction, Auger electron spectroscopy, UV and X-ray photoemission spectroscopy, electron/photon stimulated ion desorption, inelastic tunneling spectroscopy, ion scattering, surface EXAFS, and energy loss spectroscopy; and experimental aspects of these surface science techniques. Prerequisites: PHYSICS 70 and MATSCI 199/209, or consent of instructor.

3 units, not given this year

EE 334. Micro and Nano Optical Device Design

Lecture and project course on design and analysis of optical devices with emphasis on opportunities and challenges created by scaling to the micrometer and nanometer ranges. The emphasis is on fundamentals, combined with some coverage of practical implementations. Prerequisite: 242 or equivalent

3 units, Aut (Solgaard, O)

EE 335. Introduction to Information Storage Systems

State-of-the-art data storage technologies, including magnetic disk drive storage, optical data storage (CD-ROM, DVD, magneto-optic recording), solid state memory (flash memory, ferro-electric memory), and emerging technologies (magnetic random access memory, probe-based storage). Magnetic disk recording and comparisons among data storage technologies. Related nanotechnologies. Final presentation. Prerequisites: electromagnetism, optics, transistors, binary algebra, probability, and Fourier transform.

3 units, not given this year

EE 336. Nanophotonics

(Same as MATSCI 346) Recent developments in micro- and nanophotonic materials and devices. Basic concepts of photonic crystals. Integrated photonic circuits. Photonic crystal fibers. Superprism effects. Optical properties of metallic nanostructures. Subwavelength phenomena and plasmonic excitations. Meta-materials. Prerequisite: electromagnetic theory at the level of 242.

3 units, Win (Fan, S; Brongersma, M)

EE 340. Advanced Topics in Optics and Quantum Optics

Optical microcavities and their device applications. Types of optical microcavities (microdisks, microspheres, and photonic crystal cavities), and their electromagnetic properties, design, and fabrication techniques. Cavity quantum electrodynamics: strong and weak-coupling regime, Purcell factor, spontaneous emission control. Applications of optical microcavities, including low-threshold lasers, resonant cavity light-emitting diodes, and single-photon sources. Prerequisites: advanced undergraduate or basic graduate-level knowledge of electromagnetics, quantum mechanics, and physics of semiconductors.

3 units, Spr (Vuckovic, J)

EE 343. Advanced Optoelectronic Devices

Semiconductor quantum well structures; superlattices and coupled quantum wells; optical properties of quantum wells; valence band structure; effects of strain; quantum well lasers; intersubband detectors; excitons in quantum wells; absorption saturation; electroabsorption; quantum well modulators and switches. Prerequisites: 222 or equivalent quantum mechanics, 243. Recommended: 223.

3 units, Spr (Miller, D)

EE 344. High Frequency Laboratory

Lecture/lab emphasizing lab. Techniques in the 1MHz-1GHz range useful in designing and measuring oscillators, amplifiers, and mixers. High frequency measurement techniques including s-parameter measurements, amplifier noise figure, and oscillator phase noise. Guest speakers from Lucent and Hewlett-Packard. Enrollment limited to 25. Prerequisites: transmission lines, Smith charts. Recommended: 314.

3 units, Aut (Scherer, D; Swain, H; Cox, D)

EE 345. Optical Fiber Communication Laboratory

Experimental techniques in optical fiber communications. Experimental investigation of key optical communications components including fibers, lasers, modulators, photodiodes, optical amplifiers, and WDM multiplexers and demultiplexers. Key optical communications systems techniques: eye diagrams and BER measurements. Prerequisites: undergraduate physics and optics.

3 units, not given this year

EE 346. Introduction to Nonlinear Optics

Wave propagation in anisotropic, nonlinear, and time-varying media. Microscopic and macroscopic description of electric dipole susceptibilities. Free and forced waves-phasematching; slowly varying envelope approximation-dispersion, diffraction, space-time analogy; harmonic generation; frequency conversion; parametric amplification and oscillation; electro-optic light modulation; nonlinear processes in optical fibers. Prerequisites: 141, 242.

3 units, Spr (Harris, S)

EE 347. Optical Methods in Engineering Science

Design and understanding of modern optical systems. Topics: geometrical optics; aberration theory; systems layout; applications such as microscopes, telescopes, optical processors. Computer ray tracing program as a design tool. Prerequisite: 268 or 366, or equivalent.

3 units, Win (Hesselink, L)

EE 348. Advanced Optical Fiber Communications

Optical amplifiers: gain, saturation, noise. Semiconductor amplifiers. Erbium-doped fiber amplifiers. System applications: preamplified receiver performance, amplifier chains. Raman amplifiers, lumped vs. distributed amplification. Group-velocity dispersion management: dispersion-compensating fibers, filters, gratings. Interaction of dispersion and nonlinearity, dispersion maps. Multichannel systems. Wavelength-division multiplexing components: filters, multiplexers. WDM systems, crosstalk. Time-, subcarrier-, code- and polarization-division multiplexing. Comparison of modulation techniques: differential phase-shift keying, phase-shift keying, quadrature-amplitude modulation. Comparison of detection techniques: noncoherent, differentially coherent, coherent. Prerequisite: 247.

3 units, Win (Kahn, J)

EE 349. Nano Optics and Grating Photonics

Coupled wave analysis of periodic structures, gratings structures for optical communcations, wave-matter interactions with periodic media and photonic crystals, applications of periodic structures. Prerequisite: 268 or 366, or equivalent.

3 units, not given this year

EE 350. STARLab Seminar

Research topics from space physics, planetary exploration, ionospheric and magnetospheric physics, radar and remote sensing of the environment, applied electromagnetics, waves in optical fibers, and information systems with space applications. Applied research areas include wireless personal communications, high bandwidth wired and wireless transmission, optical communication systems, sensor networks, and related underlying and advancing technologies.

1 unit, not given this year

EE 354. Introduction to Radio Wave Scattering

Integral and differential equations of radio wave scattering; exact, approximate, and numerical solutions of single particle scattering for spheres, edges, points, and cylinders. Scattering from rough surfaces with large and small roughness scales, as time permits. Multiple scattering; formulation and solution techniques for equation of transfer in discrete media and scattering by continuous media in weak and strong regimes. Applications to radar, radar astronomy, remote sensing, and biological media. Prerequisites: electromagnetic theory through standard graduate engineering topics; partial differential equations, boundary value problems in rectangular and spherical coordinates; and consent of instructor.

3 units, not given this year

EE 355. Imaging Radar and Applications

(Same as GEOPHYS 265) Radar remote sensing, radar image characteristics, viewing geometry, range coding, synthetic aperture processing, correlation, range migration, range/Doppler algorithms, wave domain algorithms, polar algorithm, polarimetric processing, interferometric measurements. Applications: polarimetry and target discrimination, topographic mapping surface displacements, velocities of ice fields.

3 units, not given this year

EE 356. Elementary Plasma Physics: Principles and Applications

Plasmas in nature and industry. Single particle motions. Plasma kinetic theory. Boltzmann equation and its moments. Cold and warm plasma models. Plasma as a fluid. Magnetohydrodynamics. Plasma conductivity and diffusion. Langmuir oscillations. Debye shielding. Plasma sheath. Waves in cold, magnetized, warm, and hot plasmas. Electron and ion waves. MHD waves. Landau damping. Nonlinear effects. Applications in industry and space science. Prerequisite: 242 or PHYSICS 122.

3 units, not given this year

EE 359. Wireless Communication

Design, performance analysis, and performance limits of wireless systems. Topics include: current wireless systems, path loss and shadowing, statistical multipath channel models, capacity of wireless channels, digital modulation and its performance in fading and intersymbol interference, adaptive modulation, diversity, multiple antenna systems (MIMO), equalization, multicarrier modulation, and spread spectrum and RAKE receivers. Possible additional topics: multiuser system design issues such as multiple access, frequency reuse in cellular systems, and ad hoc wireless network design. Prerequisite: 279.

3-4 units, Aut (Goldsmith, A)

EE 360. Multiuser Wireless Systems and Networks

Design, analysis, and fundamental limits. Possible topics include multiuser detection and interference cancellation, multiple access, cellular system design and optimization, Shannon capacity and achievable rate regions of wireless multiuser channels and networks, ad hoc wireless network design, sensor and energy-constrained networks, and cross-layer design. Prerequisite: 359.

3 units, Win (Goldsmith, A)

EE 363. Linear Dynamic Systems

Continuation of 263. Optimal control and dynamic programming; linear quadratic regulator. Lyapunov theory and methods. Linear estimation and the Kalman filter. Perron-Frobenius theory. Examples and applications from digital filters, circuits, signal processing, and control systems. Prerequisites: 263 or equivalent; basic probability.

3 units, not given this year

EE 364A. Convex Optimization I

Convex sets, functions, and optimization problems. The basics of convex analysis and theory of convex programming: optimality conditions, duality theory, theorems of alternative, and applications. Least-squares, linear and quadratic programs, semidefinite programming, and geometric programming. Numerical algorithms for smooth and equality constrained problems; interior-point methods for inequality constrained problems. Applications to signal processing, communications, control, analog and digital circuit design, computational geometry, statistics, machine learning, and mechanical engineering. Prerequisite: linear algebra such as 263.

3 units, Spr (Boyd, S)

EE 364B. Convex Optimization II

Continuation of 364. Subgradient, cutting-plane, and ellipsoid methods. Decentralized convex optimization via primal and dual decomposition. Alternating projections. Exploiting problem structure in implementation. Convex relaxations of hard problems, and global optimization via branch and bound. Robust optimization. Applications in areas such as control, circuit design, signal processing, and communications. Substantial project. Prerequisite: 364A.

3 units, not given this year

EE 366. Introduction to Fourier Optics

Applications of Fourier theory to the analysis and synthesis of optical imaging and optical data processing systems. Propagation and diffraction of light, Fresnel and Fraunhofer approximations, Fourier transforming properties of lenses, image formation with coherent and incoherent light, transform functions of imaging systems, optical data processing, and holography. Prerequisite: familiarity with Fourier analysis. Recommended: 261.

3 units, Aut (Hesselink, L)

EE 368. Digital Image Processing

Image sampling and quantization, color, point operations, segmentation, linear image filtering and correlation, image transforms, eigenimages, multidimensional signals and systems, multiresolution image processing, wavelets, morphological image processing, noise reduction and restoration, simple feature extraction and recognition tasks, image registration. Students write and investigate image processing algorithms in Matlab. Competitive term project. Prerequisites: 261, 278.

3 units, Spr (Girod, B)

EE 369A. Medical Imaging Systems I
Imaging internal structures within the body using high-energy radiation studied from a systems viewpoint. Modalities covered: x-ray, computed tomography, and nuclear medicine. Analysis of existing and proposed systems in terms of resolution, frequency response, detection sensitivity, noise, and potential for improved diagnosis. Prerequisite: 261.
3 units, not given this year

EE 369B. Medical Imaging Systems II
Imaging internal structures within the body using non-ionizing radiation studied from a systems viewpoint. Modalities include ultrasound and magnetic resonance. Analysis of ultrasonic systems including diffraction and noise. Analysis of magnetic resonance systems including physics, Fourier properties of image formation, and noise. Prerequisite: 261.
3 units, Spr (Nishimura, D)

EE 369C. Medical Image Reconstruction
Reconstruction problems from medical imaging, including magnetic resonance imaging (MRI), computed tomography (CT), and positron emission tomography (PET). Problems include reconstruction from non-uniform frequency domain data, automatic deblurring, phase unwrapping, reconstruction from incomplete data, and reconstruction from projections. Prerequisite: 369B.
3 units, not given this year

EE 371. Advanced VLSI Circuit Design
Issues in high performance digital CMOS VLSI design from a system perspective. Topics: wire modeling, logic families, latch design and clocking issues, clock distribution, RAMs, ALUs, I/O and I/O noise issues. Final project involves the design of a subsystem for a high-speed processor. Extensive use of SPICE. Prerequisites: 271 and 313, or consent of instructor.
3 units, not given this year

EE 373A. Adaptive Signal Processing
Learning algorithms for adaptive digital filters. Self optimization. Wiener filter theory. Quadratic performance functions, their eigenvectors and eigenvalues. Speed of convergence. Asymptotic performance versus convergence rate. Applications of adaptive filters to statistical prediction, process modeling, adaptive noise cancelling, adaptive antenna arrays, adaptive inverse control, and equalization and echo cancelling in modems. Theoretical and experimental research projects in adaptive filter theory, communications, and audio systems. Biomedical research projects, supervised jointly by EE and Medical School faculty. Recommended: 263, 264, 278.
3 units, Win (Widrow, B)

EE 373B. Adaptive Neural Networks
Artificial neural networks. Feedforward layered networks. Back-propagation algorithm. Recurrent neural networks. Autoassociative neural networks. Principal component analysis. Clustering algorithms. Applications of neural networks to pattern recognition, speech recognition, adaptive control, nonlinear adaptive filtering, and cognitive memory. Modeling human memory. Design of human-like memory for computers, with applications to face recognition, image processing, and complex control. Continuation of research projects begun in 373A. Prerequisite: 373A.
3 units, Spr (Widrow, B)

EE 375. Quantization Noise
Statistical analysis of quantization noise in digital filters, digital control systems, digital communication systems, and in digital computation. Analog-to-digital and digital-to-analog conversion. Uniform quantization and floating-point quantization. Sampling and quantization of sinusoidal and gaussian signals. Quantizing theorems derived from Nyquist/Shannon sampling theory. Quantization analyzed as additive uniformly-distributed white noise when conditions for quantizing theorems are met. Quantizer linearization by means of additive random dither signals. Coefficient quantization in digital filters. Recommended: 278.
3 units, Aut (Widrow, B)

EE 376A. Information Theory
Extreme points of communication theory: data compression to the entropy limit, and communication at the channel capacity limit. Shannon entropy. Rate distortion theory. Huffman coding. Kolmogorov complexity. Unified treatment based on the asymptotic equipartition theorem. Prerequisite: 178 or 278 or STATS 116, or equivalent.
3 units, Win (Weissman, I)

EE 376B. Information Theory
Rate distortion theory and Kolmogorov complexity. Information theory and statistics. Method of types. Stein's lemma. AEP. Information capacity of networks. Slepian-Wolf theorem. Optimal investment and information theory. Universal portfolios and universal data compression. Maximum entropy and Burg's theorem. Prerequisite: 376A.
3 units, Spr (Cover, T)

EE 378. Statistical Signal Processing
Random signals in electrical engineering. Discrete-time random processes: stationarity and ergodicity, covariance sequences, power spectral density, parametric models for stationary processes. Fundamentals of linear estimation: minimum mean squared error estimation, optimum linear estimation, orthogonality principle, the Wold decomposition. Causal linear estimation of stationary processes: the causal Wiener filter, Kalman filtering. Parameter estimation: criteria of goodness of estimators, Fisher information, Cramer-Rao inequality, Chapman-Robbins inequality, maximum likelihood estimation, method of moments, consistency, efficiency. ARMA parameter estimation: Yule-Walker equations, Levinson-Durbin algorithm, least squares estimation, moving average parameter estimation, modified Yule-Walker method for model order selection. Spectrum estimation: sample covariances, covariance estimation, Bartlett formula, periodogram, periodogram averaging, windowed periodograms. Prerequisite: 278.
3 units, Spr (Weissman, I)

EE 379. Digital Communication
Modulation methods and bandwidth requirements, baseband and passband system analysis, minimum-probability-of-error and maximum-likelihood detection, error-probability analysis, intersymbol interference, maximum-likelihood sequence detection, equalization methods, orthogonal frequency-division multiplexing.Prerequisite: EE102A, EE278
3 units, not given this year

EE 380. Seminar on Computer Systems
Current research in the design, implementation, analysis, and use of computer systems from integrated circuits to operating systems and programming languages.
1 unit, Aut (Allison, D; Freeman, J), Win (Allison, D; Freeman, J), Spr (Allison, D; Freeman, J), Sum (Allison, D)

EE 382A. Advanced Processor Architecture
Topics include advanced instruction-set design and pipelining, wide instruction fetch, branch prediction, out-of-order and speculative execution, memory disambiguation, vector processors, simultaneous multithreading, multi-core systems, memory hierarchies, and low-level compiler optimizations for processor efficiency. Trade-offs among performance, power, and complexity, and techniques for addressing them. Design or research project in processor architecture. Prerequisites: 108B, Recommended: 282.
3 units, Aut (Kozyrakis, C)

EE 382C. Interconnection Networks
The architecture and design of interconnection networks used to communicate from processor to memory, from processor to processor, and in switches and routers. Topics: network topology, routing methods, flow control, router microarchitecture, and performance analysis. Enrollment limited to 30. Prerequisite: 282.
3 units, not given this year

EE 382D. Advanced Computer Arithmetic
Number systems, floating point representation, state of the art in arithmetic algorithms, problems in the design of high speed arithmetic units. Prerequisite: 282.
3 units, not given this year

ELECTRICAL ENGINEERING (EE)

EE 384A. Internet Routing Protocols and Standards
Local area networks: MAC addressing; IEEE 802.1 bridging protocols (transparent bridging, virtual LANs). Internet routing protocols: Internet protocol (IPv4, IPv6, ICMP); interior gateways (RIP, OSPF) and exterior gateways (BGP, policy routing); IP multicast (IGMP, DVMRP, CBT, MOSPF, PIM); multiprotocol label switching (MPLS). Prerequisite: 284 or CS 244A.
3 units, not given this year

EE 384B. Multimedia Communication over the Internet
Applications and requirements. Traffic generation and characterization: voice encoding (G.711, G.729, G.723); image and video compression (JPEG, H.261, MPEG-2, H.263, H.264), TCP data traffic. Quality impairments and measures. Networking technologies: LAN technologies; home broadband services (ADSL, cable modems, PONs); and wireless LANs (802.11). Network protocols for multimedia applications: resource reservation (ST2+, RSVP); differentiated services (DiffServ); and real-time transport protocol (RTP, RTCP). Audio-video-data conferencing standards: Internet architecture (SDP, SAP, SIP); ITU recommendations (H.320, H.323 and T.120); and real-time streaming protocol (RTSP). Prerequisite: 284 or CS 244A. Recommended: 384A.
3 units, not given this year

EE 384C. Wireless Local Area Networks
Characteristics of wireless communication: multipath, noise, and interference. Communications techniques: spread-spectrum, CDMA, and OFDM. IEEE 802.11 physical layer specifications: FHSS, DSSS, IEEE 802.11b (CCK), and 802.11a/g (OFDM). IEEE 802.11 media access control protocols: carrier sense multiple access with collision avoidance (CSMA/CA), point coordination function (PCF), IEEE802.11e for differentiated services. IEEE 802.11 network architecture: ad hoc and infrastructure modes, access point functionality. Management functions: synchronization, power management and association. Current research papers in the open literature. Prerequisite: 284 or CS 244A.
3 units, not given this year

EE 384M. Network Science
Theory and practice of designing and analyzing algorithms arising in networks. Topics include: designing algorithms for load balancing, switching, congestion control, network measurement, the web infrastructure, and wireless networks; and analyzing the performance of algorithms via stochastic network theory. Algorithm design using randomization, probabilistic sampling, and other approximation methods. Analysis methods include the use of large deviation theory, fluid models, and stochastic comparison. Research project. Prerequisite: 278 or CS 365.
3 units, not given this year

EE 384P. Projects: The Programmable Open Mobile Internet (POMI)
A new Stanford research program in EE and CS to define the next generation of mobile computing: from the handheld device and its operating system to the network, radios, and cloud computing that supports the user. Small student teams prototype part of the next Internet architecture. Emphasis is on how the Internet can support billions of mobile users. Prerequisite: EE 284, CS 244A, CS 144, or equivalents, and programming skills.
3 units, not given this year

EE 384S. Network Architectures and Performance Engineering
Modeling and control methodologies for high-performance network engineering, including: Markov chains and stochastic modeling, queueing networks and congestion management, dynamic programming and task/processor scheduling, network dimensioning and optimization, and simulation methods. Applications for design of high-performance architectures for wireline/wireless networks and the Internet, including: traffic modeling, admission and congestion control, quality of service support, power control in wireless networks, packet scheduling in switches, video streaming over wireless links, and virus/worm propagation dynamics and countermeasures. Enrollment limited to 30. Prerequisites: basic networking technologies and probability.
3 units, Spr (Bambos, N)

EE 384X. Packet Switch Architectures I
First of two-course sequence. Theory and practice of designing packet switches and routers. Evolution of switches and routers. Output scheduling: fairness, delay guarantees, algorithms. Unicast switching: blocking phenomena and their alleviation, connection between switch scheduling and bipartite graph matching. Multicast switching. Theoretical complements: simple queueing models, Bernoulli and Poisson processes, graph matching algorithms, urn problems, stability analysis using Lyapunov functions, fluid models. Prerequisites: 284 or CS 244A, 178 or 278 or STAT 116.
3 units, Spr (McKeown, N)

EE 384Y. Packet Switch Architectures II
Second of two-course sequence. Theory and practice of designing packet switches and routers. Address lookup: exact matches, longest prefix matches, performance metrics, hardware and software solutions. Packet classifiers: for firewalls, QoS, and policy-based routing; graphical description and examples of 2-D classification, examples of classifiers, theoretical and practical considerations.
3 units, not given this year

EE 385A. Robust and Testable Systems Seminar
Student/faculty discussions of research problems in the design of reliable digital systems. Areas: fault-tolerant systems, design for testability, production testing, and system reliability. Emphasis is on student presentations and Ph.D. thesis research. May be repeated for credit. Prerequisite: consent of instructor.
1-4 units, Aut (McCluskey, E; Mitra, S), Win (McCluskey, E; Mitra, S), Spr (McCluskey, E; Mitra, S), Sum (McCluskey, E)

EE 386. Robust System Design
Causes of system malfunctions; techniques for building robust systems that avoid or are resilient to such malfunctions through built-in error detection and correction, prediction, self-test, self-recovery, and self-repair; case studies and new research problems. Prerequisites: 108A,B, 282.
3 units, Spr (Mitra, S)

EE 387. Algebraic Error Control Codes
Algebraic codes for detection and correction of random and burst errors. Introduction to finite fields. Linear block codes, cyclic codes, Hamming codes, Fire codes, BCH codes, Reed-Solomon codes. Decoding algorithms for BCH and Reed-Solomon codes. Prerequisites: elementary probability, linear algebra.
3 units, not given this year

EE 388. Modern Coding Theory
Tools for analysis and optimization of iterative coding systems. LDPC, turbo and, RA codes. Optimized ensembles, message passing algorithms, density evolution, and analytic techniques. Prerequisite: 376A.
3 units, Spr (Montanari, A)

EE 390. Special Studies or Projects in Electrical Engineering
Independent work under the direction of a faculty member. Individual or team activities may involve lab experimentation, design of devices or systems, or directed reading.
1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EE 391. Special Studies and Reports in Electrical Engineering
Independent work under the direction of a faculty member; written report or written examination required. Letter grade given on the basis of the report; if not appropriate, student should enroll in 390.
1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EE 392B. Introduction to Imaging Sensors
Design and analysis: silicon photodetectors; CCD and CMOS passive and active sensor operation; noise and FPN analysis; spatial resolution and MTF; SNR and dynamic range; high dynamic range architectures; A/D conversion approaches. Analysis of the signal path in a digital camera starting from the optics, through the sensor, the A/D converter, to the different color processing steps. MATLAB camera simulator is used to explore various tradeoffs in camera design. Prerequisites: undergraduate level device, circuit, and system background equivalent to 102A, 101A,B; and familiarity with noise analysis.
3 units, not given this year

EE 392F. Logic Synthesis of VLSI Circuits
Solving logic design problems with CAD tools for VLSI circuits. Exact and heuristic algorithms for logic synthesis. Representation and optimization of combinational logic functions (encoding problems, binary decision diagrams) and of multiple-level networks (algebraic and Boolean methods, don't-care set computation, timing verification, and optimization);and modeling and optimization of sequential functions and networks (retiming), semicustom libraries, and library binding. Prerequisites: familiarity with logic design, algorithm development, and programming.
3 units, not given this year

EE 392G. Terahertz Technologies and Applications
Principles of THz wave generation, detection, and applications. Sources and systems that provide access to the THz region of the spectrum include ultrafast time-domain systems, direct generation using terahertz lasers as well as nonlinear optical frequency conversion. Terahertz measurement techniques include detector technologies, terahertz waveguides, terahertz measurements using surface plasmons, near-field effects, and nonlinear optical methods of detection. Applications of terahertz radiation including spectroscopy, sensing, and imaging, holography, terahertz communications concepts and systems, photonic crystals, and metamaterials.
3 units, not given this year

EE 392H. Coding for Wireless Channels
Theoretical foundations of modern coding theory, with applications to wireless transmission systems. State-of-the-art coding theory using soft (maximum-likelihood) decoding. Topics include: fading channel models (independent fading, block fading, MIMO); information-theoretic performance limits; coding on signal spaces; optimization criteria for code design; factor-graphical models of codes including block, convolutional, turbo, LDPC, and concatenated codes; trellis-coded modulation and bit-interleaved modulation; iterative (turbo) receivers for coded signals: memoryless, intersymbol-interference, MIMO, and multiuser channels; and EXIT-chart analyses of performance. Prerequisites: EE 278, 279. Recommended: EE 376A.
3 units, not given this year

EE 392M. Fault Diagnostics Systems
Overview of current diagnostic systems engineering practices, emphasizing approaches that are usually referred to as advanced in industry. Real life implementation constraints. Guest lectures by experts from key sectors, including aerospace, automotive, semiconductor manufacturing, networking, and enterprise computing industries. May be repeated for credit. Recommended: STATS 116; EE 263 or ENGR 207A; EE 278 or ENGR 207B.
1 unit, not given this year

EE 392R. Charged Particle Optics
Electron optics of charged particle instruments including transmission electron microscope, scanning electron microscope and related tools, mass and energy spectrometers, electron beam lithography tools, focused ion beam systems, electron diffraction, proximal probe tools such as the scanning tunneling microscope. Topics include sources, first-order focusing of electrons and ions, third-order aberrations, space-charge effects and diffraction. Goal is to compute the optical parameters of axially-symmetric magnetic and electric lenses and to be familiar with the principles of operation of the above charged-particle systems and the factors limiting their performance. Prerequisites: undergraduate geometrical optics and vector calculus or 217.
3 units, Spr (Pease, R)

EE 392T. Seminar in Chip Test and Debug
Seminars by industry professionals in digital IC manufacturing test and silicon debug. Topics include yield and binsplit modeling, defect types and detection, debug hardware, physical analysis, and design for test/debug circuits. Case studies of silicon failures. Prerequisite: basic digital IC design (271 or 371).
1 unit, Aut (Stinson, J)

EE 395. Electrical Engineering Instruction: Practice Teaching
Open to advanced EE graduate students who plan to make teaching their career. Students conduct a section of an established course taught in parallel by an experienced instructor. Enrollment limited.
1-15 units, Aut (Wong, S), Win (Wong, S), Spr (Wong, S)

EE 398A. Image and Video Compression
Replaces EE398. The principles of source coding for the efficient storage and transmission of still and moving images. Entropy and lossless coding techniques. Run-length coding and fax compression. Arithmetic coding. Rate-distortion limits and quantization. Lossless and lossy predictive coding. Transform coding, JPEG. Subband coding, wavelets, JPEG2000. Motion-compensated coding, MPEG. Students investigate image and video compression algorithms in Matlab or C. Term project. Prerequisites: 261, 278.
3 units, Win (Girod, B)

EE 398B. Image Communication II
Second of two-course series. Digital video communication techniques. Interframe coding. Conditional replenishment. Motion-compensated prediction. Motion-compensated hybrid coding. Motion estimation. Rate distortion analysis and optimization of video coding schemes. Advanced motion compensation techiques. Scalable layered video representations. Error-resilient video coding. Applications: videotelephony, videoconferencing, digital TV broadcasting, Internet video streaming, wireless video. Standards: MPEG-1, MPEG-2, MPEG-4, ITU-T, H.261, H.263, H264. Students investigate video compression algorithms in Matlab or C. Term project. Prerequisite: 398A.
3 units, not given this year

EE 400. Thesis and Thesis Research
Limited to candidates for the degree of Engineer or Ph.D.
1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EE 402A. Topics in International Technology Management
Theme for Autumn 2009 is: Technology Strategies in Asian Business. Surveys distinctive practices of major corporations and start-up companies in Japan and Asia. Open and closed innovation, tech licensing, R&D portfolio management, M&A for technology positioning and more. Distinguished speakers from industry and government.
1 unit, Aut (Dasher, R)

EE 402S. Topics in International Advanced Technology Research
Theme for 2006-07 is advanced technologies for biomedical applications. Photonic and electronic systems and components for imaging, micro--arrays, drug delivery, artificial organs, and robot-assisted surgery. Guest speakers from industry, government, and universities. May be repeated for credit. Recommended: basic electronics.
1 unit, Spr (Dasher, R)

EE 402T. Entrepreneurship in Asian High Tech Industries
Patterns and challenges of entrepreneurship in Asia. Business and technology issues in start-up companies in Asian economies. Guest speakers from industry, government, and universities. May be repeated for credit.
1 unit, Spr (Dasher, R)

EE 410. Integrated Circuit Fabrication Laboratory
Fabrication, simulation, and testing of a highly simplified 1.5 micron CMOS process developed for this course. Practical aspects of IC fabrication including silicon wafer cleaning, photolithography, etching, oxidation, diffusion, ion implantation, chemical vapor deposition, physical sputtering, and wafer testing. Students perform simulations of the CMOS process using process simulator TSUPREM4 of the structures and electrical parameters that should result from the process flow in the lab. Taught in the Stanford Nanofabrication Facility (SNF) in the Center for Integrated Systems (CIS). Preference to students pursuing doctoral research program requiring SNF facilities. Enrollment limited to 20. Prerequisites: 212, 216, consent of instructor.
3-4 units, Win (Saraswat, K)

EE 414. RF Transceiver Design Laboratory
Students design, build, and test GHz transceivers using microstrip construction techniques and discrete components. The design, construction, and experimental characterization of representative transceiver building blocks: low noise amplifiers (LNAs), diode ring mixers, PLL-based frequency synthesizers, voltage-controlled oscillators (VCOs), power amplifiers (PAs), and microstrip filters and patch antennas. The characteristics of passive microstrip components (including interconnect). Emphasis is on a quantitative reconciliation of theoretical predictions and extensive experimental measurements performed with spectrum and network analyzers, time-domain reflectometers (TDRs), noise figure meter and phase noise analyzers. Prerequisites: 314, 344.
3 units, Win (Lee, T)

EE 418. Topics in Neuroengineering
Neuroscience and electrical engineering, focusing on principles and theory in modern neural prosthetic systems (brain-computer or brain-machine interfaces). Electrical properties of neurons, information encoding, neural measurement techniques and technology, processing electronics, information decoding and estimators, and statistical data analysis. Prerequisites: 214, 278.
3 units, not given this year

EE 453. Geomagnetically Trapped Radiation
Research on the radiation belts of Earth and other planets. Physical processes which lead to magnetic trapping of electrons and ions. Analytical tools for trapped radiation research. The nature of radiation belts, source and loss mechanisms, and the relation of radiation belts to other geophysical phenomena.
3 units, not given this year

EE 469B. RF Pulse Design for Magnetic Resonance Imaging
Magnetic resonance imaging (MRI) and spectroscopy (MRS) based on the use of radio frequency pulses to manipulate magnetization. Analysis and design of major types of RF pulses in one and multiple dimensions, analysis and design of sequences of RF pulses for fast imaging, and use of RF pulses for the creation of image contrast in MRI. Prerequisite: 369B.
3 units, Aut (Pauly, J)

EE 477. Universal Schemes in Information Theory
Universal schemes for lossless and lossy compression, channel coding and decoding, prediction, denoising, and filtering. Characterization of performance limitations in the stochastic setting: entropy rate, rate-distortion function, channel capacity, Bayes envelope for prediction, denoising, and filtering. Lempel-Ziv lossless compression, and Lempel-Ziv based schemes for lossy compression, channel coding, prediction, and filtering. Discrete universal denoising. Compression-based approach to denoising. The compound decision problem. Prerequisites: 278, 376A,B.
3 units, Aut (Staff)

EE 478. Topics in Multiple User Information Theory
Topics in multiple user source and channel coding; multiple access channel, correlated source coding, broadcast channel, interference channel, relay channel, and channels with feedback; asymptotic capacity of networks; source coding with side information, multiple descriptions, channels with state, MIMO channels. Prerequisite: 376A.
3 units, not given this year

EE 479. Multiuser Digital Transmission Systems
Multiuser communications design, modulation, and reception. Capacity regions and fundamentally optimum designs for multiple access, broadcast, and interference channels. Iterative waterfilling, optimum spectrum balancing, band preference methods, vectoring, and multi-user generalized decision feedback equalization (GDFE) as used for vector broadcast and multiple access. Prerequisite: 379C.
3 units, not given this year

EE 492M. How Cyberspace Works
Introduction to information technology. The technical foundation of bits and bytes, multimedia, and networks, using the web as a starting point. Topics include representing information as bits and bytes, digital music, images, video, computer graphics, and virtual reality. Data compression, JPEG, MPEG audio, and video. Bandwidth and sampling. Analog, digital, and wireless telephone systems. Digital transmission and storage: modulation, error control; cable, fiber, satellite, storage media. Broadcasting. GPS. Circuit-versus packet-switched networks, local-area networks, Ethernet, Internet. Email, VoIP. Security: encryption, digital signatures, digital certificates. Field-trip to a Silicon Valley information technology company.
3 units, Win (Paulraj, A)