ELECTRICAL ENGINEERING

Emeriti: (Professors) James B. Angell, Clayton W. Bates, Ronald N. Bracewell, Marvin Chodorow, Von R. Eshleman,* Michael J. Flynn,* Gene F. Franklin,* Joseph W. Goodman, Robert A. Helliwell,* Martin E. Hellman, Thomas Kailath,* William R. Kincheloe, Gordon S. Kino,* John G. Linvill, Albert Macovski,* Laurence A. Manning, Malcolm M. McWhorter, James D. Meindl, Richard H. Pantell,* William R. Rambo, Anthony E. Siegman, William E. Spicer,* David F. Tuttle, Alan T. Waterman, Robert L. White; *(Professors, Research)* Donald L. Carpenter,*Aldo da Rosa,* Antony Fraser-Smith,* C. Robert Helms, Ingolf Lindau,* David Luckham

Chair: Bruce A. Wooley

Vice Chair: Robert M. Gray

Associate Chairs (Admissions): R. Fabian Pease, Dwight G. Nishimura

Assistant Chair: Sharon A. Gerlach

Professors: Nicholas Bambos, Stephen P. Boyd, John M. Cioffi, Thomas M. Cover, Donald C. Cox, William J. Dally, Giovanni De Micheli, Robert W. Dutton, Abbas El Gamal, Hector Garcia-Molina, Bernd Girod, Robert M. Gray, Patrick Hanrahan, James S. Harris, Stephen E. Harris, John L. Hennessy, Lambertus Hesselink, Mark A. Horowitz, Umran S. Inan, Joseph M. Kahn, Edward J. McCluskey, Teresa H. Y. Meng, David A. B. Miller, Dwight G. Nishimura, Brad G. Osgood, R. Fabian W. Pease, James D. Plummer, Krishna Saraswat, Fouad A. Tobagi, Leonard Tyler, Bernard Widrow, S. Simon Wong, Bruce A. Wooley, Yoshihisa Yamamoto

Associate Professors: Dan Boneh, John T. Gill III, Andrea J. Goldsmith, Gregory T. A. Kovacs, Thomas H. Lee, Nick McKeown, Marc S. Levoy, Bruce B. Lusignan, Dwight G. Nishimura, Oyekunle Olukotun, John Pauly, Balaji Prabhakar, Dwight G. Nishimura, Olav Solgaard, Shan X. Wang, Jennifer Widom, Howard A. Zebker

Assistant Professors: Mary G. Baker, Dawson Engler, Shanhui Fan, Christoforos E. Kozyrakis, Krishna V. Shenoy, Benjamin VanRoy, Jelena Vuckovic, Tsachy Weissman

Professors (Research): James F. Gibbons, Leonid Kazovsky, Butrus Khuri-Yakub, Yoshio Nishi, Arogyaswami J. Paulraj, Krishna Saraswat, Leonard Tyler

Courtesy Professors: John Bravman, David Cheriton, David L. Dill, Per Enge, Gary Glover, Peter Glynn, Gene Golub, Donald E. Knuth (emeritus), Monica S. Lam, David G. Luenberger, Richard Olshen, Norbert Pelc, Zhi-Xun Shen, Brian Wandell, Gio Wiederhold (emeritus), Yinyu Ye

Courtesy Associate Professors: Stacey Bent, Sandy Napel, Mendel Rosenblum, Julius Smith, Daniel Spielman

Courtesy Assistant Professors: Armando Fox, Sanjay Lall, David H. Liang, Hari Manoharan, Michael McConnell, Claire Tomlin

Courtesy Associate Professor (Research): Peter Fitzgerald

Lecturers: Dennis Allison, Heinz Blennemann, Brian Hargreaves, Krishna Nayak, Dieter Scherer, Howard Swain, John Wharton

Consulting Professors: Elizabeth Cohen, Abbas Emami-Naeini, Michael Godfrey, Dimitry Gorinevsky, Timothy Groves, Sam Haddad, Bob S. Hu, Theodore Kamins, Earl Killian, John Koza, David Leeson, Michel Marhic, Dan Meisburger, Roger D. Melen, Madihally Narasimha, Debajyoti Pal, Kurt Petersen, Richard Reis, David Stork, John Wakerly, Manjula Waldron, Martin Walt

Consulting Associate Professors: Ahmad Bahai, Richard Dasher, Ludwig Galambos, Nadim Maluf, Yi-Ching Pao, Nirmal Saxena, Noel Thompson

Consulting Assistant Professors: John Apostolopoulos, David Burns, Mar Hershenson, Patrick Hung, My T. Le, Subhasish Mitra, Ashok Popat, David Su, Katelijn Vleugels, Susie Wee, Jun Ye

Visiting Professors: Mitsuteru Inoue, Kuen-Jong Lee

Visiting Associate Professors: Luca Benini, Conor Heneghan, Yoshinori Matsumoto

Teaching Fellows: Azita Emami-Nayestanak, Maksin Kamentsky

*recalled to active duty

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Web Site: http://ee.stanford.edu/

Courses given in Electrical Engineering have the subject code EE. For a complete list of subject codes, see Appendix B.

UNDERGRADUATE PROGRAMS

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 of 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, Electronics, Fields and Waves, and Communication and Signal Processing.
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, post-graduate 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 specialize in Electrical Engineering (EE), undergraduate students 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.

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 the "School of Engineering" coterminal section of this bulletin.

HONORS

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 students 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.

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 Electrical Engineering courses.
2. complete at least 9 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.

GRADUATE PROGRAMS

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 relation 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-year program of graduate study in electrical engineering may lead to the degree of Master of Science. The program is typically completed in four academic quarters. A two-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 if you have web access, or a printed application may be obtained by writing to Graduate Admissions, the Registrar's Office, 520 Lasuen Mall, Old Union Building, Stanford, CA 94305-3055. Applications are submitted to and reviewed by the Department of Electrical Engineering, Graduate Admissions Office, 350 Serra Mall, Stanford University, Stanford, CA 94305-9505. Applications for full-time study are considered for the Autumn Quarter only. The application deadline is December 16th.

Applicants who have not yet earned the equivalent of an M.S. degree should apply for admission to study first toward the master's degree, indicating any intention of later working toward a more advanced degree. Admission for either the Engineer or Ph.D. degree is normally available only to students who have completed a master's degree. In addition, candidacy to the Engineer or Ph.D. degree also requires that the department's Committee on Graduate Admissions identify a tentative faculty research supervisor.

MASTER OF SCIENCE

Modern electrical engineering is a broad and diverse field, and graduate education in this department may satisfy a variety of objectives. 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 will ordinarily be able to complete the master's degree in four academic quarters which may require more than one calendar year because many courses are not taught during the summer. It is possible to complete the program within a calendar year, but the majority of students take longer. 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 on 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 later. 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 quarter units that meet the following guidelines are normally approved:

1. A sequence of three or more 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 EE course numbered above 200 in each of three additional course areas, outside of the area selected under item 1 to provide breadth.
3. Enough additional units of electrical engineering courses so that items 1 through 3 total at least 21 units of 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.
4. Additional course work to bring the total to 45 or more quarter units, including:
   a) at least 36 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 among these 30 units.
5. The EE 201A seminar in Autumn Quarter and either (a) at least one formal seminar course for credit, or (b) attend a minimum of eight informal or formal 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 all students sample the many available research seminars. In case of conflict with EE 201A, tapes may be viewed in the Terman Library.

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 his or her 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 electrical engineering demands that students be adequately prepared in circuits, digital systems, electronics, fields, lab work, mathematics, and physics. Skill in using modern computing facilities is essential for electrical engineers, and an increasing number of our courses routinely require it. 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 should contain more than the typical 45 units, and the time required to meet the degree requirements may be increased.

Permission to study beyond the M.S. degree must be obtained from the department (if possible, well before the M.S. degree is received). The student needs to file a Graduate Program Authorization Petition. Permission is predicated on the applicant's academic record, performance in independent work, potential for advanced study, and on the ability of the faculty to supervise such study. For the most recent information, see http://ee.stanford.edu/gradhandbook/ms.html.

ENGINEER

The degree of Engineer requires a minimum of two academic years (90 quarter units) of study beyond the B.S. degree (three academic quarters beyond the M.S.) including six full-time quarters of approved work as a graduate student, of which a minimum of three quarters and 36 quarter units must be in residence at Stanford.

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, his 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

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.

Not later than the first Autumn Quarter after receiving the M.S. degree, the applicant should submit an application to take the department qualifying examination (given each Winter Quarter). Upon successful 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. Only after receiving department approval to that application does the student become a candidate for the Ph.D. degree.

Requirements may be summarized as follows. The student must complete successfully (1) a minimum of three years of residence with graduate standing, two years of which must be in residence at Stanford; (2) one or more qualifying examinations given by the faculty of the Department of Electrical Engineering; (3) an approved program of courses in electrical engineering and allied subjects; (4) an approved topic 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.

About one-fourth of the program of graduate study should be in departments other than Electrical Engineering. Courses shall be selected to form an integrated program, to be approved by the department. A student wishing to fulfill the requirements for a formal minor may elect to do so. For the most recent information, see http://ee.stanford.edu/gradhandbook/phd.html.

Ph.D. MINOR

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.

FINANCIAL ASSISTANCE

The department annually awards a limited number of fellowships, teaching assistantships, and research assistantships to incoming graduate students. The fellowships are usually awarded only to first-year graduate students in the EE Master of Science program. Most awards to Engineer and Ph.D. candidates are research assistantships, which are awarded by individual faculty research supervisors working in conjunction with the department Committee on Graduate Admissions. Research assistants are often able to write their theses as an integral part of the assistantship. To be considered for department assistance, applicants are only required to submit the admission application materials.

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.

AREAS OF RESEARCH

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 areas listed below.

COMMUNICATIONS

Adaptive Modulation and Coding
Adaptive Multiuser Coding and Reception
Applied Optics and Optoelectronics
Cellular Radio Systems/Networks
Coding and Coded Modulation
Communication Channels and Signal Propagation
Communication and Information Theory
Digital Subscriber Lines
Digital Transmission
Frequency Reuse in Large Wireless Networks
Mobility in Wireless Networks
Multicarrier Modulation and OFDM
Multipath Mitigation Techniques
Multiple Access Techniques
Multiple Antenna and MIMO Systems
Optical Communications
Optical Networks
Optoelectronic Components and Systems
Resource Allocation/Channel Assignment/Handoff in Wireless Networks
Wavelength Division Multiplexing
Wireless Ad-Hoc Networks
Wireless Communications
Wireless Local Area Networks
Wireless Personal Communication Systems

COMPUTER SYSTEMS

Asynchronous Circuits
Compilers
Computer-Aided Design
Computer Architecture
Computer Graphics
Computer Networks
Computer Organization
Computer Reliability
Concurrent Languages
Concurrent Processes and Processors
Database and Information Systems
Distributed Systems
Embedded System Design
Hardware/Software Co-Design
Hardware Verification
Human Computer Interaction
Multimedia Systems
Operating Systems
Performance Measurement and Modeling
Programming Languages
Program Verification
VLSI Design

INFORMATION SYSTEMS

Adaptive Control and Signal Processing
Adaptive Neural Networks
Biomedical Signal Analysis
Computer-Aided Design and Analysis of Systems
Data Communications
Digital Signal Processing
Estimation Theory and Applications
Fourier and Statistical Optics
Information and Coding Theory
Medical Imaging and Image Processing
Multivariable Control
Optical Communications
Optimization-Based Design
Pattern Recognition and Complexity
Quantization and Data Compression
Real-Time Computer Applications
Signal Processing
Speech and Image Coding

INTEGRATED CIRCUITS

Analog Integrated Circuits
Bipolar, MOS, and other Device and Circuit Technologies
CAD of Processes, Devices, and Equipment
Custom Integrated Circuits for Computers and Telecommunications
Digital Integrated Circuits
Integrated Sensors and Actuators
Mixed Signal Integrated Circuits
Nanostructures
Optoelectronic Integrated Circuits
Process, Device, Circuit, and Equipment Modeling
Sensors and Control for VLSI Manufacturing
VLSI Device Structures and Physics
VLSI Fabrication Technology
VLSI Materials, Interconnections, and Contacts
VLSI Packaging and Testing

LASERS AND QUANTUM ELECTRONICS

Coherent UV and X-Ray Sources
Free-Electron Lasers
Laser Applications in Aeronautics, Biology, Chemistry, Communications, Electronics, and Physics
Laser Devices and Laser Physics
Nonlinear Optical Devices and Materials
Optoelectronic Devices
Photoacoustic Phenomena
Semiconductor Diode Lasers
Ultrafast Optics and Electronics

MICROWAVES, ACOUSTICS, AND OPTICS

Acoustic Microscopy
Acousto-Optic Devices
Fiber Optics
Holography
Microwave Integrated Circuits and Devices
Nondestructive Testing
Optical Interferometry
Scanning Optical Microscopes

RADIOSCIENCE AND REMOTE SENSING

Environmental Studies using Satellite Technology
Exploration of the Earth from Space
Interferometric and Holographic Imaging with Radio Waves
Numerical Methods for Science Data Analysis
Optical Remote Sensing
Planetary Exploration
Radar Interferometry
Radar Remote Sensing
Radio Occultation Studies
Radio Wave Scattering
Remote Sensing of Atmospheres and Surfaces
Signal and Image Processing Methods
Space Data Management
Spaceborne Radio Receiver Development
Synthetic Aperture Radar Satellites

SOLID STATE

Applied and Fundamental Superconductivity
Crystal Preparation: Epitaxy and Ion Implantation, and Molecular Beam Epitaxy
Defect Analysis in Semiconductors
Electron and Ion Beam Optics
Electron Spectroscopy
Experimental Determination of the Electronic Structure of Solids
High Resolution Lithography
Laser, Electron, and Ion Beam Processing and Analysis
Magnetic Information Storage
Magnetic Materials Fundamentals and Nanostructures
Nanostructure Fabrication and Applications
Molecular Beam Epitaxy
Novel Packaging Approaches for Electronic Systems
Optoelectronic Devices
Physics and Chemistry of Surfaces and Interfaces
Semiconductor and Solid State Physics
Solid State Devices: Physics and Fabrication
Ultrasmall Electron and Photodevices

SPACE PHYSICS AND ELECTROMAGNETICS

Computational Electromagnetics
Detection of Electromagnetic Fields from Earthquakes
Electromagnetic Waves and Plasmas
Geomagnetically Trapped Radiation
Ionospheric and Magnetospheric Physics
Ionospheric Modification
Lightning Discharges
Lightning-Ionosphere Interactions
Space Engineering (also see the “Space Science and Astrophysics” section of this bulletin)
Ultra-Low Frequency Fluctuations of the Earth’s Magnetic Field
Very Low Frequency Wave Propagation and Scattering

COURSES

(WIM) indicates that the course satisfies the Writing in the Major requirements. (AU) indicates that the course is subject to the University Activity Unit limitations (8 units maximum).

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

020-099 first or second year
100-199 third or fourth year
200-299 mezzanine course 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 Systems Engineering
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
VLSI Design

UNDERGRADUATE

EE 17Q. From Chips to Genes: Engineering the MicroWorld—Stanford Introductory Seminar. Preference to sophomores. Each session consists of a lecture by instructor or guest speaker followed by demonstration or hands-on experimentation. Instruments available include light microscopes, scanning electron microscope, scanning tunneling microscope, microlithography tools. Applications include microelectronics, microelectro-mechanical systems (MEMS), and biotechnology. Reading assignments and final project. Prerequisite: high school physics.
3 units, Spr (Pease) alternate years, not given 2004-05

EE 41. Introduction to Electrical Engineering—The physics behind 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.
5 units, Win (Horowitz, Miller, Solgaard)

EE 42. Mathematics of Information Systems—A survey of mathematical ideas and techniques that support the physical, perceptual, and practical understanding of information. The mathematical background for more specialized courses in signal processing and related areas. Topics include: analog and digital signals and their representations; the spectrum of a signal; sampling, quantizing and coding; entropy and channel capacity; error correction; compression; communication systems and networks; encryption and security; imaging systems. Prerequisite: ENGR 154 or MATH 51. Recommended: programming knowledge or MATLAB.
3 units, Spr (Osgood)

EE 45. Science and Technology in WW II and What Happened Afterward—The efforts of engineers, mathematicians, and scientists during WWII. The effect on the postwar world in areas such as information, communication, transportation, materials, and medicine. Examples of science and counter science in the war effort, and what became of them after the war, drawn from: encryption and computation; radar, communication, and electronics; control and optimization; materials; drugs and medicine. GER:2b
3 units, Win (Osgood)

EE 60Q. Science of the Earth's Environment: Understanding Change Using Satellite Technology—(Same as GEOPHYS 60Q.) Stanford Introductory Seminar. Preference to sophomores. What are the physical reasons behind changes in the Earth's environment? Why does human influence lead to global warming? What is the ozone hole and how does it affect us? How does deforestation impact the global carbon cycle? The Earth as a system with emphasis on global change. Readings address the science behind global change, spaceborne instrumentation for measuring change, and remote sensing data and analysis. Hands-on experimentation with remote sensing images of the Earth to identify surface terrain types and land cover, and which surface characteristics can be studied using spaceborne data.
3 units, Aut (Zebker)

EE 93Q. Energy Processes—Stanford Introductory Seminar. Preference to sophomores. Serves as preparation for 293A,B. Topics in non-traditional energy processes. Students groups of 2 or 3 each select one topic for further investigations. Progress reports, final report. Discussions on the physics and chemistry of the processes, concentrating on a journalistic description of what is being accomplished in each area and the near term prospects. Prerequisite: interest in science and engineering in the energy area.
3 units, Aut (da Rosa)

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 (Gray)

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.
4 units, Win (Wong, Horowitz)

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, feedback. Design and use of operational amplifiers. Prerequisite: 101A.
4 units, Aut (Shenoy, Hershenson), Spr (Shenoy, Dutton)

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. Continuous-discrete time signal conversion and quantization. Stability and causality in linear systems. Laplace transforms and Bode plots. Feedback and control system design. Examples from filter design and linear control.
4 units, Win (Pauly, Gray)

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.
4 units, Spr (Pauly, Gray)

SCHOOL OF ENGINEERING

EE 103. Introduction to Signal Processing—Introduction to analog signal processing, filter synthesis, discrete-time systems, z-transforms, sampling, and quantization. Digital signal processing and filter synthesis. Discrete Fourier Transform and FFT. Prerequisite: 102.
3 units, Aut (Kamenetsky)

EE 105. Feedback Control Design—(Enroll in ENGR 105.)
3 units, Win (Rock)

EE 108A. Digital Systems I—Digital circuit, logic, and system design. Digital representation of information. CMOS logic circuits. Digital transmission lines. 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.
4 units, Aut (Dally), Win (Gill)

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.
4 units, Win (Olukotun), Spr (Kozyrakis)

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, photo-detectors). Introduction to quantum effects and band theory of solids. Prerequisite: ENGR 40. Corequisite: 101A.
3 units, Aut (Dutton)

EE 118. Introduction to Mechatronics—(Same as CS 118.) Technologies involved in Mechatronics (Intelligent Electro-Mechanical Systems) and the techniques necessary 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; basic mechanical design (machine elements and mechanical CAD). Lab component of structured assignments combined with a large and open-ended team project. Limited enrollment. Prerequisite: ENGR 40 and CS 106A.
4 units, Win (Carryer)

EE 122. Analog Circuits Laboratory—Introduces the practical applications of analog circuits, including simple amplifiers, filters, oscillators, power supplies, and sensors. Goals: lab experience, basic design skills, experience with computer-aided design, and basic circuit fabrication/debugging knowledge. Prerequisite: ENGR 40 or equivalent.
3 units, Aut, Spr (Kovacs)

EE 133. Analog Communications Design Laboratory—The design and testing of analog communications circuits, including 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 the systematic building and characterization of AM and FM modulation/demodulation circuits and subsystems. Enrollment limited to 30 undergraduate and coterminal EE students. Prerequisites: 113, 122.
3 units, Win (Dutton)

EE 134. Introduction to Photonics—Lectures and laboratory experiments on 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. Prerequisite: 141 or equivalent.
4 units, Spr (Solgaard)

EE 137. Laboratory Electronics—(Enroll in APPPHYS 207.)
3 units, Spr (Fox)

EE 138. Laboratory Electronics—(Enroll in APPPHYS 208.)
3 units, Spr (Fox) alternate years, given 2004-05

EE 140. The Earth from Space: Introduction to Remote Sensing—(Enroll in GEOPHYS 140.)
3 units, Aut (Zebker) alternate years, not given 2003-04

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: 102, MATH 52.
4 units, Aut (Inan)

EE 142. 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 (Inan)

EE 144. Wireless Electromagnetic Design Laboratory—(Same as 245.) Hands-on experiments and projects with antennas, transmission lines, and propagation for wireless communications and remote sensing. Using spectrum analysers, swept frequency generators, frequency counters, couplers, detectors and slotted lines, develop measurement and design capability in the 1-20 GHz range in support of chosen design projects. Two- to three-person team projects from antenna, guided wave distributed circuits, remote sensing, or related topics. Working model constructed and demonstrated; some funding available for project costs. Prizes for best projects. Lab. Enrollment limited to 30. Prerequisites: 122, 142, or consent of instructor.
3 units, Spr (Leeson)

EE 167. Introductory Computer Graphics—(Enroll in CS 148.)
3 units, Win (Johnson)

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.
3-4 units, Win (Zebker)

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. Prerequisite: basic calculus and linear algebra.
3 units, Win (Prabhakar)

EE 179. Introduction to Communications—Communication system design and performance analysis. Concepts from Fourier analysis and transform techniques that characterize random signals. Topics include current communication systems (cellular, WLANs, radio and TV broadcasting, satellites, Internet), Fourier techniques, energy and power spectral density, characterization of random signals, analog modulation (AM and FM) and its performance in noise, digital modulation (PSK and QAM), optimal receiver design, and digital modulation performance in noise. Prerequisite: 102A.
3 units, Win (Goldsmith)

EE 181. Introduction to Computer Systems and Assembly Language Programming—(Enroll in CS 110.)
3-4 units (Staff) not given 2003-04

EE 184. Programming Paradigms—(Enroll in CS 107.)
3-5 units, Aut, Spr (Cain)

EE 189A. Object-Oriented Systems Design—(Enroll in CS 108.)
3-4 units, Aut (Parlante), Win (Staff)

EE 189B. Software Project—(Enroll in CS 194.)
3 units, Win (Young), Spr (Plummer)

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, by arrangement (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, by arrangement (Staff)

EE 192. Special Seminars—Special seminars and experimental courses are given on topics of current interest by specialists in the field. Announcements are made one or two quarters prior to presentation. See *Time Schedule* and bulletins in the department office for current listing.
by arrangement (Staff)

UNDERGRADUATE AND GRADUATE

EE 201A. Seminar—Weekly discussions of topics of current interest in electrical engineering. Orientation to Stanford and to the EE department. Students with a conflict may view via videotape in the library. (AU)
1 unit, Aut (Reis)

EE 201B. Seminar—Life after Stanford through presentations primarily directed at MS/EE students. The activities of graduates in industry, startups, government laboratories, and community colleges. (AU)
1 unit, Win (Reis)

EE 202. Medical Electronics—Open to non-EE students also. Primarily biological in nature, introduction to the physiological and anatomic aspects of medical instrumentation. Areas include patient monitoring, imaging, medical transducers, the unique aspects of medical electronic systems, the socio-economic impact of technology on medical care, and the constraints unique to medicine. Prerequisite: familiarity with circuits and electrical instrumentation techniques, such as 113.
3 units, Aut (Thompson)

EE 203. The Entrepreneurial Engineer—Seminar furthers the knowledge base of prospective entrepreneurs with an engineering background. The 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. (AU)
1 unit, Win (Melen)

EE 205. Introduction to Control Design Techniques—(Enroll in ENGR 205.)
3 units, Aut (Tomlin)

EE 206. Control System Design and Simulation—(Enroll in ENGR 206.)
4 units, Spr (Niemeyer)

EE 207D. Optimal Control and Hybrid Systems—(Enroll in AA 278.)
3 units (Tomlin) not given 2003-04

EE 209A. Analysis and Control of Nonlinear Systems—(Enroll in ENGR 209A.)
3 units, Win (Tomlin)

EE 209B. Advanced Nonlinear Control—(Enroll in ENGR 209B.)
3 units, Spr (Tomlin)

EE 210B. Advanced Topics in Computation for Control—(Enroll in ENGR 210B.)
3 units, Aut (Lall)

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 are used to illustrate concepts and provide a virtual lab experience. Topics: the fundamental 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. Prerequisites: 111, 112 or equivalent.
3 units, Aut (Plummer)

EE 213. Heat Transfer in Microdevices—(Enroll in ME 358.)
3 units, Spr (Goodson)

EE 214. Analog Integrated Circuit Design—Analysis and design of MOS analog integrated circuits, emphasizing quantitative measures of performance, figures of merit, and circuit limitations. Evaluation of circuit performance by means of hand calculations and computer-aided circuit simulations. Design of operational amplifiers, broadband amplifiers, biasing circuits, and voltage references. Feedback amplifier design. History of analog integrated circuits; historical survey of integrated operational amplifiers. Prerequisite: 113.
3 units, Aut (Lee)

EE 216. Principles and Models of Semiconductor Devices—The fundamentals of carrier generation, transport, recombination, and storage in semiconductors. The physical principles of operation of the p-n junction, metal semiconductor contact, bipolar junction transistor, MOS capacitor, MOS and junction field-effect transistors, and related opto-electronic 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. Prerequisites: 111, 112, or equivalent.
3 units, Aut (J. Harris)

EE 217. Electron and Ion Beams for Semiconductor Processing—Focused and flood beams of electrons and ions are employed for processing semiconductor devices. The generation of such beams including thermionic emission, field-induced emission, first-order focusing and glow discharge processes. The interactions of such beams with the target, including scattering in solids, the distribution of energy, heating, sputtering, beam-induced etching (including reactive-ion etching) and beam-induced deposition. Introduction to computer modeling of etching and deposition. Prerequisite: 212.
3 units (Pease) alternate years, given 2004-05

EE 222. Applied Quantum Mechanics I—(Same as APPPHYS 150/222.) Introduction to quantum mechanics, with emphasis on applications in modern devices and systems. Topics include: Schrödinger's equation; eigenfunctions and eigenvalues; operator approach to quantum mechanics; solutions of simple problems including quantum wells, harmonic oscillators; tunneling; calculation techniques; including matrix diagonalization, perturbation theory, and variational method; and time-dependent perturbation theory including application to optical absorption. Prerequisites: PHYSICS 65, or 45 and 47 or equivalents; MATH 43 or equivalent.
3 units, Aut (Vuckovic)

EE 223. Applied Quantum Mechanics II—(Same as APPPHYS 151/223.) Continuation of 222. Spin and identical particles, effective mass theory for semiconductors, annihilation and creation operators, introductory quantum optics, and other topics in electronics, optoelectronics, and optics. Prerequisite: 222.
3 units, Win (Vuckovic)

EE 226. Physics of Quantum Information—(Enroll in APPPHYS 226.)
3 units (Yamamoto) alternate years, given 2004-05

EE 227. Application of Quantum Information—(Enroll in APPPHYS 227.)
3 units (Yamamoto) alternate years, given 2004-05

EE 228. Basic Physics for Solid State Electronics—The physics underlying modern solid state materials and devices. Topics: the energy band theory of solids, energy bandgap engineering, classical kinetic theory, statistical mechanics, equilibrium and non-equilibrium semiconductor statistics. Prerequisites: 112, PHYSICS 70 or any course in modern physics.
3 units, Aut (Fan)

EE 229B. Thin Film and Interface Microanalysis—(Enroll in MATSCI 323.)
3 units, Aut (Brongersma)

EE 229D. Introduction to Magnetism and Magnetic Nanostructures—(Enroll in MATSCI 347.)
3 units, Spr (Wang)

EE 231. Introduction to Lasers—Introduction to lasers and how they 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; uses classical models for atomic transitions with little quantum mechanics background required. Prerequisites: electromagnetic theory to a level of at least 142, preferably 241, and some knowledge of atomic or modern physics such as PHYSICS 57 or 130-131.
3 units, Aut (Fejer)

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, Win (Fejer)

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. Prerequisite: 142.
3 units, Aut (Solgaard)

EE 235. Guided Wave Optical Devices—Guided wave optics, optical waveguide devices, and integrated optics. Review of 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: working knowledge of electromagnetic theory to the level of 142 or equivalent.
3 units, Spr (Fan)

EE 236. Solid State Physics I—(Enroll in APPPHYS 272.)
3 units, Win (Manoharan)

EE 237. Solid State Physics II—(Enroll in APPPHYS 273.)
3 units, Spr (Manoharan)

EE 238. Electronic and Optical Properties of Solids—(Enroll in MATSCI 199/209.)
3-4 units, Spr (Brongersma)

EE 241. Waves I—Waves and wave phenomena as they appear in natural, lab, and application settings. Electromagnetic, acoustic, seismic, atmospheric, plasma, and water waves and their mathematical and physical correspondence in terms of Hamilton's principle. Propagation, attenuation, reflection, refraction, surface and laminal guiding, and intrinsic and structural dispersion; energy density, power flow, and phase and group velocities. Geometric and structural complexities are minimized to stress basic wave concepts. Analysis in terms of transmission line and impedance concepts using exponential notation and vector phasors. Treatment limited to plane harmonic waves in isotropic media. Nonhomogeneous cases limited to plane interfaces and exponentially stratified media. Prerequisites: 142 or equivalent, or other wave course.
3 units, Aut (Staff)

EE 243. Semiconductor Optoelectronic Devices—Introduction to semiconductor optoelectronic devices for communications and other applications, covering operating principles and practical device features. Review of relevant semiconductor physics, and optical processes in semiconductors. Semiconductor heterostructures. Semiconductor optical detectors (including p-i-n, avalanche, and MSM), light emitting diodes, electroabsorptive modulators (Franz-Keldysh, QCSE), electrorefractive (directional couplers, Mach-Zehnder), switches (SEEDs), and lasers (waveguide and vertical cavity). Prerequisites: basic quantum mechanics, solid state physics, lasers (e.g., 222, 228, 231, or equivalents).
3 units, Win (J. Harris)

EE 244. Communication Engineering Transmission Systems—Design of transmission systems for TV, telephone, and data-using satellites; microwave repeaters; mobile radio; and broadcast transmitters. Performance of FM, AM, and SSB common digital schemes; TDMA, FDMA, and CDMA; voice, TV and data compression; and error coding. Emphasis is on link performance, capacity, total system design, and cost optimization. Current industry design problems and research results. Examples illustrate modern technologies providing service to rural populations. Project on social and economic factors, and detailed network design for a student-selected rural area. Prerequisites: senior or graduate standing in Electrical Engineering, or consent of instructor.
3 units, Aut (Lusignan)

EE 245. Wireless Electromagnetic Design Laboratory—(Same as 144; see 144.) Same content as 144 but with a higher level project.
3 units, Spr (Leeson)

EE 246. Microwave Engineering—Microwave applications (terrestrial and satellite communications, radar, remote sensing, wireless communications) and their system and component requirements. Review of Maxwell's equations. Propagation modes of transmission lines (TEM, waveguide, microstrip), S-parameter matrix modeling of discontinuities, junctions and circuits (impedance transformers, directional couplers, hybrids, filters, circulators, solid state amplifiers and oscillators). Microwave computer-aided design examples. General flow of course is application to system to component; individual components are modeled by fields to modes to equivalent network. Prerequisite: 142.
3 units, Aut (Leeson) alternate years, not given 2004-05

EE 247. Introduction to Optical Fiber Communications—Fibers: multi- and single-mode, attenuation, chromatic dispersion. Sources: light-emitting diodes, edge- and surface-emitting lasers, single- and multi-mode lasers, linewidth, intensity noise, direct modulation, chirp. Modulators: Mach-Zehnder, electro-absorption. Photodiodes: p-i-n, avalanche, responsivity, capacitance, transit time. Receivers: high-impedance, transimpedance, bandwidth, dynamic range, noise. Amplifiers:

semiconductor, doped fiber, gain, noise, optical signal-to-noise ratio, amplifier chains. Digital modulation formats: non-return-to-zero, return-to-zero, Q factor, bit-error ratio, receiver sensitivity, quantum limit. Analog modulation formats, signal-to-noise ratio. Digital transmission: time-division multiplexing, access, metropolitan and long-haul networks. Analog transmission: subcarrier multiplexing, video distribution. Wavelength-division multiplexing. Prerequisites: 104 or 261, 142 or 235 or 241. Corequisite: 278 or 279.

3 units, Aut (Kahn)

EE 248. Fundamentals of Noise Processes—Introduction to statistical processes and Fourier analysis: binomial, Gaussian, and Poisson distributions; time averaging vs. ensemble averaging; Parseval and Wiener-Khintchine theorems. Thermal noise and quantum noise: fluctuation-dissipation theorem, Johnson-Nyquist formula, zero-point fluctuation. Noise of junction devices, amplifiers and oscillators: van der Pol oscillator and parametric oscillator. Noise consideration of communication and weak force detection systems. Prerequisites: familiarity with elementary device, circuit, and electromagnetic waves to the level of 111 and 142.

3 units (Yamamoto) not given 2003-04

EE 249. Introduction to the Space Environment—Introduction to the environment through which mankind's space probes and vehicles travel and orbit and which moderates the gases and radiation from the Sun. Experimentation in this environment, the tools used, and the regions into which it is divided including the ionosphere, the magnetosphere, 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: familiarity with electromagnetics at the level of 142 and senior or graduate standing.

3 units, Aut (Fraser-Smith) alternate years, not given 2004-05

EE 251. Progress in Worldwide Telecommunications—(Enroll in MS&E 237.)

3 units, Sum (Ivanek, Chiu)

EE 252. Antennas for Telecommunications and Remote Sensing—Fundamental parameters. 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: 142 or equivalent.

3 units (Staff) alternate years, given 2004-05

EE 254. Principles of Radar Systems—Analysis and design, emphasizing radars as systems. Radar equation and systems parameters, components of radar systems, radar cross-section and target characteristics, signal detection in noise, ambiguity function (with applications to measurement precision, resolution, clutter rejection, and waveform design); pulse compression waveforms, synthetic aperture radar, tracking and scanning radars, HF (OTH) radar, radar environmental and remote sensing, radar astronomy. Prerequisite: senior undergraduate or graduate standing.

3 units, Aut (Zebker) alternate years, not given 2004-05

EE 256. Numerical Electromagnetics—The 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. Step and pulse response of lossy transmission lines and interconnects. Absorbing boundary conditions. FDTD modeling of propagation and scattering indispersive media. Near-to-far-zone transformations. Moment method solutions of integral equations, with applications to antenna problems. Computational problems require programming and use of MATLAB and other tools. Prerequisite: 142 or equivalent.

3 units (Inan) alternate years, given 2004-05

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, crystalography. Emphasis is on relating the theoretical principles to solving practical engineering and science problems. Prerequisites: previous exposure to Fourier series at the level of 102, and linear algebra.

3 units, Aut (Osgood), Win (Hesselink)

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 layergarm 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. Prerequisites: 261. Recommended: 278, 279.

3 units (Zebker) alternate years, given 2004-05

EE 263. Introduction to Linear Dynamical Systems—Introduction to 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. Least-norm inputs and associated Gramians. Prerequisite: exposure to basic linear algebra and matrices (as in MATH 103); differential equations and Laplace transforms (as in 102).

3 units, Aut (Boyd)

EE 264. Digital Filtering—Introduction to modern digital signal processing techniques. Two sided Z-transform. SISO and MIMO flowgraphs, Markov graphs. Discrete-time Wiener filtering. Laplace transform, mixed discrete and continuous feedback systems. Interpolation techniques for D/A conversion. Discrete Fourier transform and its applications. Finite impulse response (FIR) and infinite impulse response (IIR) filter designs. Theory of quantization noise. Prerequisite: 103. Recommended: 261, 278.

3 units, Aut (Widrow)

EE 265. 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, IIR filters, FIR filters, filter design and implementation, spectral analysis, audio signal processing, rate conversion, wireless data communication. Prerequisite: 103. Recommended: 261.

4 units, Aut, Win (Meng)

EE 268. Introduction to Modern Optics—Geometrical optics: raymatrices, 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 (Hesselink) alternate years, not given 2004-05

EE 268L. Introduction to Modern Optics: Laboratory—Laboratory experiments on geometrical optics, Gaussian beams, interferometry, and wave propagation in fibers and graded index media. Corequisite: 268.

1 unit (Staff) not given 2003-04

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 circuits, logic design, and digital system organization.
3 units, Aut (Emami-Neyestanak)

EE 273. Digital Systems Engineering—Fundamental 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 affect on signaling, and methods for noise reduction; timing conventions; timing noise (skew and jitter), its affect 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: 121 and 113, or equivalents.
3 units, Win (Staff)

EE 274. Introduction to Cryptography—(Enroll in CS 255.)
3 units, Win (Boneh)

EE 275. Logic Design—Principles and techniques of logic design. Combinational circuit analysis (hazard detection); combinational circuit design including PLA, VLSI, and MSI techniques and testing techniques; IC logic, flipflop properties, sequential circuit analysis and synthesis for fundamental and pulse mode circuits, design for testability techniques. Prerequisite: 121 or equivalent.
3 units, Aut (Saxena), Win (McCluskey)

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. Prerequisites: 142 and 278 or equivalent. Corequisite: 279 or equivalent.
3 units, Spr (Cox)

EE 277. Stochastic Decision Models—(Enroll in MS&E 251.)
3 units, Win (Veinott)

EE 278. Introduction to Statistical Signal Processing—Random variables, vectors, and processes; time averages, expectations, and laws of large numbers; stationarity, autocorrelation and spectral analysis; mean square error estimation, detection, and linear filtering; independent increment, Gaussian, and Poisson random processes. Prerequisites: 178 or STATS 116, and linear systems and Fourier transforms at the level of 102 or 261.
3 units, Aut (Gill), Win (El Gamal)

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 analysis, probability of error in digital systems, spread spectrum. Prerequisites: 104 or 261, and 178 or 278.
3 units, Win (Cox)

EE 281. Embedded System Design Laboratory—Architecture and design of microprocessor-based systems. Lab experiments use Atmel AVR microcontroller evaluation boards. Five-week individual design project. Lab. Prerequisites: 108A or 121; 108B or 182 or equivalent experience in assembly language programming.
3 units (Staff) alternate years, given 2004-05

EE 282. Computer Architecture and Organization—The structure of systems using general purpose processors, memories, input/output (I/O) devices, and interfaces as building blocks. Advanced design techniques, evaluation methodology, and design trade-offs. Builds on basic knowledge of instruction sets and assembly programming, elementary pipelining, and simple cache hierarchies. Prerequisite: 182 or 108B.
3 units, Aut, Win (Kozyrakis)

EE 283. Compilers—(Enroll in CS 143.)
3-4 units, Aut (Aiken), Spr (Johnson)

EE 284. Introduction to Computer Networks—(Winter Quarter, enroll in CS 244.) 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. Prerequisite for Winter Quarter: CS 140 or equivalent.
3-4 units, Aut (Tobagi), Win (McKeown)

EE 285. Programming Languages—(Enroll in CS 242.)
3 units, Aut (Mitchell)

EE 286A. Operating Systems and Systems Programming—(Enroll in CS 140.)
3-4 units, Aut, Win (Rosenblum)

EE 286B. Advanced Topics in Operating Systems—(Enroll in CS 240.)
3 units, Win, Spr (Engler)

EE 287. Introduction to Computer Graphics—(Enroll in CS 248.)
3-5 units, Aut (Levoy)

EE 288. Mathematical Methods for Robotics, Vision, and Graphics—(Enroll in CS 205.)
3 units, Aut (Fedkiw)

EE 289. Introduction to Computer Vision—(Enroll in CS 223B.)
3 units, Win (Thrun)

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

EE 292. Special Seminars

EE 292A. Global Positioning Systems—(Enroll in AA 272C.)
3 units, Win (Enge)

EE 292B. Electronic Documents: Paper to Digital—Core technologies that underlie and enable the transformation of paper documents and document collections to digital form. Scanner technology and digital camera hardware, document image analysis including optical character recognition (OCR), textual information retrieval, document representation technologies including structured and hypertext document standards, image and text compression, electronic book engineering, digital rights management technologies, data encryption and security, knowledge management, and user interface design. Emphasis is on basic technological principles. Guest lectures from PARC innovators. Term project. Prerequisites: basic probability and linear algebra, programming skills. Recommended: 103 or 168.
3 units (Popat) alternate years, given 2004-05

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, Win (Van Roy)

EE 293A. Fundamentals of Energy Processes—For seniors and graduate students. Theory of modern energy conversion, transmission, and storage methods. Windmills. Heat engines: classical engines, ocean thermal energy converters, thermoelectric, thermoionic, and radio-noise engines. Prerequisites: PHYSICS 55, MATH 43, or equivalent.
3 units, Aut (da Rosa)

EE 293B. Fundamentals of Energy Processes—For seniors and graduate students. Fuel cells. Production of hydrogen: electrolytic, chemical, thermolytic, photolytic. Hydrogen storage: hydrides. Insolation. Photoelectric converters; photo-thermovoltaic converters. Biomass: photosynthesis, production of methane and ethanol from vegetable matter. Prerequisites: PHYSICS 55, MATH 43, or equivalent.
3-4 units, Win (da Rosa)

GRADUATE

EE 300. Master's Thesis and Thesis Research—For students who wish to do independent work under the direction of a department faculty member as part of their master's degree program. 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, by arrangement

EE 310. Integrated Circuits Technology and Design Seminar—Device structures, fabrication technologies, and circuit design issues in integrated circuits. Introduces current research topics in these areas. (AU)
1 unit, Aut (Lee, Wooley)

EE 311. Advanced Integrated Circuit Fabrication Processes—Advanced Integrated Circuit Fabrication-What are the practical and fundamental limits to the evolution of the technology of modern MOS and bipolar devices? How are modern devices and circuits fabricated and what future changes are likely? Advanced techniques and models of device and back-end (interconnect and contact) processing. Use of TSUPREM4 and PISCES for process and device modeling. MOS and bipolar process integration. Prerequisites: 212, 216.
3 units, Spr (Saraswat)

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. Basic mechanisms of transduction, fabrication techniques, and the relative merits of different technologies. Micromachining techniques for monolithic integration of active circuits with sensors or actuators and directions for future research. Prerequisite: 212 or equivalent.
3 units, Win (Kovacs)

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, dyanamic and pass logic, pulse-mode gates, and current-mode logic. Topics include sizing for min delay, noise and noise margins, power dissipation. Memory design (SRAM) as a motivating example. DRAM and EEPROM design issues. Prerequisites: 101B, 108A. Recommended: 271.
3 units, Win (Staff)

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 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. Prerequisite: 214.
3 units, Win (Lee)

EE 315. VLSI Data Conversion Circuits—Design of mixed-signal integrated circuits for implementing the interfaces between analog and digital signals in CMOS VLSI systems. Fundamental circuit elements such as sample-and-hold circuits, comparators, voltage references, operational amplifiers, gain blocks, and analog integrators. The design of the constituent circuits for Nyquist-rate and oversampling analog-to-digital and digital-to-analog converters, sampled-data and continuous-time analog filters, and digital decimation and interpolation filters. Prerequisite: 214.
3 units, Spr (Wooley)

EE 316. Advanced VLSI Devices—In modern VLSI technologies, MOS and bipolar 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 submicron structures, control of electrical characteristics (threshold voltage, breakdown voltage, current gain) in small structures, and alternative device structures for VLSI. Prerequisites: 212, 216, or equivalent.
3 units, Win (Wong)

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. The use of phase-shifting masks and other wavefront-engineering approaches. Extensive hands-on use of computer simulations of each of the above steps. Prerequisites: 141 or equivalent, 212 or equivalent, basic competence in computing.
3 units, Spr (Pease) alternate years, not given 2004-05

EE 318. Logic Synthesis of VLSI Circuits—Solving logic design problems with CAD tools for VLSI circuits. Analysis and design of exact and heuristic algorithms for logic synthesis. Topics: representation and optimization of combinational logic functions (encoding problems, binary decision diagrams), representation and optimization of multiple-level networks (algebraic and Boolean methods, don't-care set computation, timing verification, and optimization), 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, Win (DeMicheli)

EE 319. Computer-Aided System Design Laboratory—Computer-aided design of VLSI systems: theory and practice. Topics: modeling languages (e.g., Verilog), high-level synthesis and optimization methods (scheduling, binding, data-path, and control synthesis), design of systems with low power consumption, and hardware/software co-design. Individual/group projects involve the use of CAD tools. Prerequisite: 318.
3 units, Spr (DeMicheli)

EE 320. Automatic Formal Verification Techniques—(Enroll in CS 356.)
3 units Aut (Dill) alternate years, not given 2004-05

EE 321. MEMS Design—Theory and practice of MEMS design. Micromechanical fundamentals and CAD tools for definition, design and layout of MEMS. Case studies of successful MEMS engineering projects. Emphasis is on physical understanding and elementary modeling, not numerical simulations. Students complete a MEMS design project which includes layout, evaluation strategy, and modeling. Prerequisite: 312 or equivalent.
3 units (Solgaard) alternate years, given 2004-05

EE 325. Nanoscale Science, Engineering, and Technology—(Enroll in MATSCI 316.)
3 units, Win (McGehee)

SCHOOL OF ENGINEERING

EE 326. Organic Semiconductors for Electronics and Photonics—(Enroll in MATSCI 343.)

3 units, Spr (McGehee)

EE 327. Properties of Semiconductor Materials—Modern semiconductor devices and integrated circuits are based on the unique energy band, carrier transport, and optical properties of semiconductor materials. These physical properties can be chosen and optimized for operation of semiconductor devices. Emphasis is on the quantum mechanical foundations of the properties of solids, energy bandgap engineering, semi-classical 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 non-radiative recombination. Prerequisites: 216, 228.

3 units (J. Harris) alternate years, given 2004-05

EE 328. Physics of Advanced Semiconductor Devices—The principles governing the operation of modern semiconductor devices. Underlying assumptions and approximations commonly made in analyzing devices. Emphasis is on the application of semiconductor physics to the development of advanced semiconductor devices (e.g., heterojunctions, HJ-bipolar transistors, HJ-FETs, nano structures, tunneling, single electron transistor and photonic devices). Use of ATLAS and MEDICI 2-D Poisson solvers for simulation of ultra-small devices. Examples are related to up-to-date device research. Prerequisite: 216.

3 units, Spr (J. Harris) alternate years, not given 2004-05

EE 329. The Electronic Structure of Surfaces and Interfaces—Basic physical concepts and phenomena for surface science techniques probing the electronic structure of surfaces and interfaces. Microscopic and atomic models in understanding microstructures have technologically important applications such as within semiconductor device technology and catalysis. Basic 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 or equivalent, 238 or consent of instructor.

3 units (Pianetta) alternate years, given 2004-05

EE 335. Introduction to Information Storage Systems—State-of-the-art data storage technologies including optical data storage (CD-ROM, DVD, magneto-optic recording, and holographic recording), solid state memory (flash memory, ferroelectric memory, and emerging magnetic random access memory), probe-based storage, and magnetic disk drives. Magnetic disk recording and comparisons among data storage technologies The increasing importance of related nanotechnologies. Prerequisites: basic electromagnetism, optics, transistors, binary algebra, probability, and Fourier transform.

3 units, Win (Wang)

EE 336. Nanophotonics—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. Sub-wavelength phenomena and plasmonic excitations. Meta-materials.

3 units, Win (Fan, Brongersma)

EE 338A. Quantum Optics and Measurements—(Enroll in APPPHYS 387.)

3 units, Win (Yamamoto) alternate years, not given 2004-05

EE 338B. Mesoscopic Physics and Nanostructures—(Enroll in APPPHYS 388.)

3 units, Spr (Yamamoto) alternate years, not given 2004-05

EE 340. Advanced Topics in Optics and Quantum Optics—This year's topic is 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)

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.

3 units, Spr (Miller) alternate years, not given 2004-05

EE 344. High Frequency Laboratory—Combination lecture/lab emphasizing the lab. Techniques in the 1MHz-1GHz range useful in designing and measuring oscillators, amplifiers, and mixers. Basic high frequency measurement techniques including s-parameter measurements, Amplifier Noise Figure; and oscillator phase noise. Lectures by the professor and experts from Lucent and Hewlett-Packard. (Two lectures, one lab weekly.) Enrollment limited to 20. Prerequisites: good understanding of transmission lines, Smith charts.

3 units, Aut (Cox)

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. Prerequisite: 247.

3 units (Kazovsky) alternate years, given 2004-05

EE 346. Introduction to Nonlinear Optics—Wave propagation in anisotropic, non-linear, 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, 142.

3 units, Spr (S. Harris)

EE 347. Optical Methods in Engineering Science—The 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 is used for demonstrations and as a design tool. Prerequisites: 268 or 366, or equivalent.

3 units, Spr (Hesselink) alternate years, not given 2004-05

EE 348. Advanced Optical Fiber Communications—Wavelength-division multiplexing: multiplexers, add-drop multiplexers, tunable filters, channel spacing, crosstalk, filter distortion. Chromatic dispersion, dispersion-shifted fibers, compensation techniques, impact on systems. Polarization-mode dispersion, compensation techniques, impact on systems. Semiconductor amplifiers, facet reflectivity, polarization sensitivity, gain saturation, intermodulation. Doped-fiber amplifiers, pumping bands, gain saturation, boosters, in-line amplifiers, receiver preamplifiers. Stimulated Raman scattering, Raman amplifiers, lumped vs. distributed amplification. Kerr nonlinearities, effective length, self- and cross-phase modulation, four-wave mixing, phase matching, management of nonlinearities, nonlinear Schrödinger equation, solitons. Modulation techniques: return-to-zero and variants, differential phase-shift keying, phase-shift keying. Detection techniques: interferometric, coherent, optical phase-locked loops. Error-correction coding. Optical switching and networks. Prerequisite: 247.

3 units, Win (Kahn)

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. Prerequisites: 268 or 366, or equivalent.
3 units (Hesselink) alternate years, given 2004-05

EE 350. Radioscience Seminar—Seminars by university and industrial researchers on 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. Student-faculty discussions. (AU)
1 unit, Aut (Zebker), Win (Inan)

EE 352. Electromagnetic Waves in the Ionosphere and Magnetosphere—Magneto-ionic theory in multi-component media, signal dispersion, group ray velocity, wave polarization, refractive index surfaces, ray tracing, absorption, boundary effects, interpretation of natural phenomena (whistlers, VLF emissions), remote sensing in plasmas, communication, theory of wave-particle interactions in the magnetosphere. Prerequisite: 142 or equivalent.
3 units (Helliwell) alternate years, given 2004-05

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. Consent of instructor.
3 units (Tyler) alternate years, given 2004-05

EE 355. Radar Remote Sensing: Fundamentals and Geophysical Application of Imaging Radar—(Enroll in GEOPHYS 265.)
3 units, Spr (Zebker) alternate years, not given 2004-05

EE 356. Elementary Plasma Physics: Principles and Applications—Plasmas in nature and industry. Basic plasma characteristics. Single particle motions. Plasma kinetic theory. The 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 plasmas. Waves in magnetized plasmas. Waves in warm plasmas. Electron and ion waves. MHD waves. Waves in hot plasmas. Landau damping. Nonlinear effects. Applications in industry and space science. Prerequisite: 142 or PHYSICS 122.
3 units (Inan) alternate years, given 2004-05

EE 358A. Lasers Laboratory—(Enroll in APPPHYS 304.)
3 units, Win (Byer)

EE 358B. Nonlinear Optics Laboratory—(Enroll in APPPHYS 305.)
3 units, Spr (Byer)

EE 359. Wireless Communication—Design, performance analysis, and fundamental performance limits of wireless communication systems. Topics include: overview of 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. Multiuser system design issues such as multiple access, frequency reuse in cellular systems, and ad hoc wireless network design. Prerequisites: 276, 279.
3 units, Aut (Goldsmith)

EE 360. Wireless Networks—Current research topics. Topics change annually depending on student interest and recent research developments. Possible topics include multiuser detection and interference cancellation, cellular system design and optimization, dynamic resource allocation and power control, handoff and mobility management, access and channel assignment, wireless network routing, Shannon capacity and achievable rate regions of wireless networks, ad hoc wireless network design, sensor and energy-constrained networks, QoS support, and joint network and application design. Prerequisite: 359.
3 units, Spr (Goldsmith) alternate years, not given 2004-05

EE 361A. Modern Control Design I—(Enroll in ENGR 207A.)
3 units, Win (Lall)

EE 361B. Modern Control Design II—(Enroll in ENGR 207B.)
3 units, Spr (Lall)

EE 362. Applied Vision and Image Systems—(Enroll in PSYCH 221.)
1-3 units (Wandell) not given 2003-04

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, Win (Boyd) alternate years, not given 2004-05

EE 364. Convex Optimization with Engineering Applications—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 unconstrained problems; interior-point and ellipsoid methods for constrained problems. Applications to signal processing, communications, control, analog and digital circuit design, computational geometry, statistics, and mechanical engineering. Prerequisites: working knowledge of linear algebra (such as 263), background in applications, and willingness to program in Matlab.
3 units (Boyd) alternate years, given 2004-05

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 (Hesselink) alternate years, given 2004-05

EE 367A. Audio Applications of the Fast Fourier Transform (FFT)—(Enroll in MUSIC 420.)
3-4 units, Win (J. Smith)

EE 367B. Signal Processing Methods in Musical Acoustics—(Enroll in MUSIC 421.)
3-4 units, Spr (J. Smith)

EE 367C. Perceptual Audio Coding—(Enroll in MUSIC 422.)
3 units, Win (Bosi)

EE 368. Digital Image Processing—Image sampling and quantization, point operations, 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. Emphasis is on the general principles of image processing. Students write and investigate image processing algorithms in Matlab. Competitive term project. Prerequisites: 261, 278.
3 units, Spr (Girod)

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, computerized tomography, and nuclear medicine. Analysis of existing and proposed systems in terms of resolution, modulation transfer function, detection sensitivity, noise, and potential for improved diagnosis. Prerequisite: 261.
3 units (Staff) not given 2003-04

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)

EE 369C. Medical Image Reconstruction—Reconstruction from non-uniform frequency domain data, automatic deblurring, phase unwrapping, reconstruction from incomplete data. Examples drawn from fast magnetic resonance imaging methods including spiral, echo-planar, multi-coil/parallel and partial k-space reconstructions. Prerequisites: 369A,B.
3 units, Aut (Pauly)

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, 313, or consent of instructor.
3 units, Spr (Horowitz)

EE 372. Quantization and Compression—Theory and design of codes for quantization and signal compression systems (source coding systems), systems which convert analog or high bit rate digital signals into low bit rate digital signals while optimizing fidelity subject to available communication or storage capacity. Applications to the design of systems for compression, statistical classification, and density estimation using statistical clustering techniques. Asymptotic theory: Zador/Gersho theory for high rate quantization theory and Shannon rate-distortion theory. Code structures: uniform and lattice codes, tree structured codes, transform codes, composite codes, universal codes. Mismatch and dithering. Prerequisites: 261, 278. Recommended: 376A, MATH 137.
3 units, Aut (Gray) alternate years, not given 2004-05

EE 373A. Adaptive Signal Processing—Self-optimizing systems whose performance is improved through contact with their environments. Feedback models for least mean-square adaptation processes. Steepest descent, Newton's method, and Southwell relaxation methods. Random search. LMS algorithm. Efficiency measures for adaptive processes. Adaptive digital filters, noise canceling and signal enhancement, adaptive antennas, adaptive control systems. Original theoretical and experimental research projects in electrical engineering and biomedical engineering, teamwork. Prerequisites: 263, 264. Recommended: 278.
3 units, Win (Widrow)

EE 373B. Adaptive Neural Networks—Adaptive threshold elements, Feedforward layered networks, Back propagation algorithm. Optimal decision making. Learning by punish/reward. Adaptive gaming. Experimental and theoretical applications of neural networks to pattern recognition, speech recognition, and self-learning adaptive control systems. Nonlinear adaptive filtering. Volterra adaptive filtering. Self-organizing maps. Support vector machines. Radial basis functions. Recurrent neural networks. Original theoretical and experimental research projects in electrical engineering and biomedical engineering, teamwork. Continuation of projects begun in 373A. Prerequisite: 373A.
3 units, Spr (Widrow)

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

EE 376B. Information Theory—Rate distortion theory and Kolmogorov complexity. Information theory and statistics. Stein's Lemma. AEP. Information capacity of networks. Slepian-Wolf Theorem. Optimal investment and information theory. Maximum entropy and Burg's Theorem. Prerequisite: 376A.
3 units (Cover) alternate years, given 2004-05

EE 377A. Dynamic Programming and Stochastic Control—(Enroll in MS&E 351.)
3 units, Spr (Veinott)

EE 377B. Approximate Dynamic Programming—(Enroll in MS&E 339.)
3 units, Win (Van Roy)

EE 379A. Digital Communication I—Maximum-likelihood data detection, modulation methods and bandwidth requirements, bandpass systems and analysis, intersymbol interference and equalization methods, diversity, phase-locking, and synchronization. Prerequisites: 103, 278.
3 units, Win (Ekbal)

EE 379B. Digital Communication II—Basic channel capacity formulae, decoding algorithms: Viterbi detection, sequence detectors, and iterative decoding methods; partial-response methods, convolutional, trellis, turbo codes, and low-density parity check codes. Prerequisites: 278, 379A.
3 units (Cioffi) alternate years, given 2004-05

EE 379C. Advanced Digital Communication—Multi-dimensional modulation and basis functions, transmit optimization for channels with intersymbol interference, discrete multitone (DMT), orthogonal frequency division multiplexing (OFDM), vector modulation, generalized decision-feedback equalization (GDFE).
3 units (Cioffi) alternate years, given 2004-05

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. (AU)
1 unit, Aut, Win, Spr (Allison, Wharton)

EE 381A. Database System Implementation—(Enroll in CS 346.)
3-5 units, Aut (Widom)

EE 381B. Transaction Processing and Distributed Databases—(Enroll in CS 347.)
3 units, Spr (Staff)

EE 383. Advanced Compiling Techniques—(Enroll in CS 243.)
3-4 units, Win (Lam)

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, Win (Tobagi)

EE 384B. Multimedia Communication over the Internet—Applications and requirements. Multimedia 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 quality measures. Advances in networking technologies for multimedia applications: LAN technologies; broadband services to the home (ADSL, cable modems, PONs) and wireless LANs (802.11). Advances in network protocols for multimedia applications: resource reservation (ST2+, RSVP); differentiated services (DiffServ); real-time transport protocol (RTP, RTCP). Audio-video-data conferencing standards: the Internet architecture (SDP, SAP, SIP); ITU recommendations H. 320, H. 323 and T.120; real-time streaming protocol (RTSP). Prerequisite: 284 or CS 244A. Recommended: 384A.

3 units (Staff) not given 2003-04

EE 384C. Wireless Local Area Networks—Multipath, noise, and interference. Communications techniques: spread-spectrum, CDMA, and OFDM. IEEE 802.11 physical layer specifications: IEEE 802.11b (FHSS and DSSS), and 802.11a (OFDM). IEEE 802.11 media access control protocols: carrier sense multiple access with collision avoidance (CSMA/CA) and point coordination function (PCF). IEEE 802.11 Network architecture: ad hoc and infrastructure modes, access point functionality. Management functions: synchronization, power management and association. Advances in IEEE 802.11 standards: new physical layer specifications (IEEE 802.11g) and differentiated services (IEEE 802.11e). Other wireless network standards: Bluetooth, HIPERLAN, IEEE 802.15.

3 units, Spr (Tobagi) alternate years, not given 2004-05

EE 384D. Projects in Computer Networks—(Enroll in CS 344.)

3 units, Spr (McKeown)

EE 384M. Network Algorithms—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.

3 units, Spr (Prabhakar)

EE 384S. Network Architectures and Performance Engineering—(Same as MS&E 334.) Modeling and control methodologies used in network performance engineering: Markov chains and stochastic modeling, queueing networks, stochastic simulation, dynamic programming, network optimization algorithms, large-scale distributed computation for networking operations. Applications to design issues in high-performance network architectures for wireline and wireless networking: traffic modeling, congestion control, IP network dynamics, TCP flow control, quality of service support, network admission control and operations management, power control and dynamic bandwidth allocation in wireless networks. Prerequisites: 284 and good understanding of probability and general systems modeling.

3 units, Spr (Bambos)

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, Win (McKeown, Prabhakar)

EE 384Y. Packet Switch Architectures II—Second of two-course sequence. The 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, Spr (McKeown, Prabhakar)

EE 385. Special Seminars in Computer Systems—Given occasionally and usually announced 1 or 2 quarters in advance. See the *Time Schedule* and bulletins in the department office.

1-4 units, by arrangement (Staff)

EE 385A. Digital Systems Reliability 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. Prerequisite: consent of instructor.

1-4 units, Aut, Win, Spr (McCluskey)

EE 386A. Parallel Computer Architecture and Programming—(Enroll in CS 315A.)

3 units, Spr (Olukotun)

EE 387. Error-Correcting Codes—Theory and implementation of 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, Spr (Gill)

EE 388. Programming Language Design—(Enroll in CS 342.)

3 units (Mitchell) not given 2003-04

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, by arrangement

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, by arrangement

EE 392. Special Seminars

EE 392A. Database System Principles—(Enroll in CS 245.)

3 units, Win (Garcia-Molina)

EE 392B. Introduction to Image Sensors and Digital Cameras—Introduction to the design and analysis of image sensors and digital cameras. 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. Topics: photodetectors; CCD and CMOS passive and active sensor operation; noise and FPN analysis; spatial resolution and MTF; SNR and dynamic range; A/D conversion approaches; color interpolation, correction, and balance; and autofocus. A MATLAB camera simulator is used to explore various tradeoffs in camera design. Prerequisites: undergraduate level device, circuit, and system background, e.g., equivalent to 102, 111, 112, and 113; and some familiarity with noise analysis.

3 units (El Gamal) alternate years, given 2004-05

EE 392C. Advanced Topics in Computer Architecture: Polymorphic Processors—Topics related to the architecture, programming model, and compilation techniques for single-chip multiprocessors. Polymorphic architectures provide a promising solution for next generation, general-purpose processing substrate for embedded and server computing. A polymorphic processor is a single-chip multiprocessor with coarse-grain reconfiguration abilities. Processing nodes can be programmed to emulate instruction-level, data-level, and thread-level parallel architectures. On-chip memory can be configured to operate as cache, scratch-pad SRAM, and hardware FIFO. Recommended: 282 or equivalent; architecture or systems background.

3 units (Staff) not given 2003-04

EE 392J. Digital Video Processing—Spatio-temporal sampling, motion analysis, parametric motion models, motion-compensated filtering, and video processing operations including noise reduction, restoration, superresolution, deinterlacing and video sampling structure conversion, and compression (frame-based and object-based methods). Video segmentation and layered video representations, video streaming, compressed-domain video processing, and digital TV. Prerequisite: 368.

3 units, Win (Apostolopoulos, Wee) alternate years, not given 2004-05

EE 392K. Genetic Algorithms and Genetic Programming—(Enroll in CS 426.)
3 units, Aut (Koza)

EE 392O. Optimization Projects—Project-based. Some topics not covered in 364, including subgradient methods, decomposition and decentralized convex optimization, exploiting problem structure in implementation, global optimization via branch and bound, and convex-optimization based relaxations. Applications in areas such as control, circuit design, signal processing, and communications. Substantial small group project. Prerequisite: 364 or consent of instructor. Limited enrollment..
3 units, Aut (Boyd) alternate years, not given 2004-05

EE 392Q. Mobile and Wireless Networks and Applications—(Enroll in CS 444N.)
3 units (Baker) not given 2003-04

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)

EE 395. Electrical Engineering Instruction: Practice Teaching—Open to limited number of 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.
1-15 units, by arrangement

EE 398A. Image Communication I—First of two-course series. Principles and systems for digital image communication, emphasizing source coding for efficient storage and transmission of still and moving images. Fundamentals and still image communication techniques. Lossless coding principles. Arithmetic coding, run-length coding. Facsimile coding. Lossy compression principles, scalar quantization, vector quantization. Lossless and lossy predictive coding. Transform coding. Multiresolution coding, subband coding, and wavelets. EZW and SPIHT coding. Embedded image representations. Standards: ITU-T T.4, T.6, JBIG, JPEG, JPEG-2000. Students investigate image compression algorithms in Matlab. Prerequisites: 261, 278.
3 units, Win (Girod)

EE 398B. Image Communication II—Second of two-course series. Digital video communication techniques. DPCM. Interframe coding. 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, Spr (Girod)

EE 399. Topics in Computer Vision—(Enroll in CS 328.)
3 units (Staff) not given 2003-04

EE 400. Thesis and Thesis Research—Limited to candidates for the degree of Engineer or Ph.D. Satisfactory/no credit.
1-15 units, by arrangement

EE 402A. Topics in International Technology Management—Theme for 2003-04 is doing business with technology in Asia. Issues and trends include outsourced manufacturing, offshore research and development partnerships, access strategies for key Asia high-tech markets, export controls, and intellectual property management. Distinguished guest speakers from industry and government. (AU)
1 unit, Aut (Dasher)

EE 402S. Topics in International Advanced Technology Research—Theme for 2003-04 is advanced sensing technologies and networks. A worldwide snapshot of leading research into molecular-level biosensing and chemical sensing via various technologies, distributed sensor networks, and related information processing. Distinguished speakers from industry, government, and universities. (AU)
1 unit, Spr (Dasher)

EE 402T. Entrepreneurship in Asian High Tech Industries—Business and technology issues in the creation and growth of Asian startups, and patterns of entrepreneurship in Asia. Speakers include entrepreneurs, investors, inventors, and consultants, and others from government and academia.
1 unit, Spr (Dasher)

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)

EE 414. Design of Discrete RF Circuits for Communications Systems—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 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, Spr (Lee)

EE 469A. In Vivo Magnetic Resonance Spectroscopy and Imaging—(Enroll in RAD 226.)
3 units, Aut (Spielman)

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, source coding with side information, multiple descriptions, channels with state, MIMO channels. Prerequisite: 376A.
3 units, Aut (El Gamal) alternate years, not given 2004-05

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. Multiuser detection, crosstalk, matrix channel descriptions, iterative waterfilling, vectoring, and multi-user generalized decision feedback equalization (GDFE).
3 units (Cioffi) alternate years, given 2004-05

EE 481A. Computer Graphics: Geometric Modeling—(Enroll in CS 348A.)
3-4 units, Win (Guibas)

EE 481B. Computer Graphics: Image Synthesis Techniques—(Enroll in CS 348B.)
3-4 units, Spr (Hanrahan)

EE 482A. Advanced Computer Organization: Processor Microarchitecture—High-performance computer design focusing on the microarchitecture of high-performance processors. Topics: pipelining, memory systems, out-of-order issue, branch prediction, and vector processors. Design project. Enrollment limited to 30. Prerequisite: 282.
3 units (Dally) alternate years, given 2004-05

EE 482B. Advanced Computer Organization: Interconnection Networks—High-performance computer design focusing on interconnection networks used from processor-memory and processor-processor communication. Topics: network topology, routing methods, flow control, router microarchitecture, and performance analysis. Enrollment limited to 30. Prerequisite: 282.
3 units (Dally) alternate years, given 2004-05

EE 483. Computer Architecture and Compilers for Embedded Applications—(Enroll in CS 343.)
3 units, Spr (Lam)

EE 484. Topics in Computer Graphics—(Enroll in CS 448.)
1-3 units, by arrangement (Staff)

EE 485. Broad Area Colloquium for Artificial Intelligence, Geometry, Graphics, Robotics, and Vision—(Enroll in CS 528.)
1 unit, Aut, Win, Spr (Staff)

EE 486. 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 (Staff) alternate years, given 2004-05

EE 488. Testing Aspects of Computer Systems—The fundamental principles of testing computer systems and designing for testability. Failure and fault models. Deterministic and probabilistic techniques of test generation and testing. Techniques for testing memories and microprocessors. Design for testability. Prerequisite: 275.
3 units (McCluskey) alternate years, given 2004-05

EE 489. Fault Tolerant Computing Systems—The design of reliable computing systems. Concurrent checking techniques. Redundancy and evaluation methods. System considerations. Examples of system designs. Prerequisite: 282.
3 units (McCluskey) alternate years, given 2004-05

EE 492. Special Seminars

EE 492M. Space-Time Wireless Communications—For EE graduate students and wireless systems engineers. Space-time (ST) wireless communications offer performance improvements in capacity, coverage, and quality. Aspects of ST technology are already part of 2.5G/3G systems. More advanced aspects (MIMO) are being incorporated into several standards. Prerequisites: 276, 278, 279. Recommended: 359.
3 units, Win (Paulraj) alternate years, not given 2004-05

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