6. COURSEWORK

6.1 Course Descriptions

For the most current list of courses, their webpages, and class schedules please refer to the lists located at: http://www.eecs.berkeley.edu/education/courses.shtml.

6.1.1 Electrical Engineering

Electrical Engineering Lower Division Courses

20N. Structure and Interpretation of Systems and Signals. (4) Three hours of lecture and three hours of laboratory per week. *Prerequisites: Mathematics 1B.* Mathematical modeling of signals and systems. Continuous and discrete signals, with applications to audio, images, video, communications, and control. State-based models, beginning with automata and evolving to LTI systems. Frequency domain models for signals and frequency response for systems, and sampling of continuous-time signals. A Matlab-based laboratory is an integral part of the course. (F,SP) *Ayazibar*

24. Freshman Seminar. (1) One hour of seminar per week. Sections 1-2 to be graded on a letter-grade basis. Sections 3-4 to be graded on a *passed/not passed* basis. The Freshman Seminar Program has been designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small seminar setting. Freshman seminars are offered in all campus departments, and topics may vary from department to department and semester to semester. (F,SP)

40. Introduction to Microelectronic Circuits. (4) Students will receive one unit of credit for 40 taking 42 and no credit after taking 100. Three hours of lecture, three hours of laboratory, and one hour of discussion per week. *Prerequisites: Mathematics 1B and Physics 7B.*Fundamental circuit concepts and analysis techniques in the context of digital electronic circuits. Transient analysis of CMOS logic gates; basic integrated-circuit technology and layout. (F,SP) *Chang-Hasnain*

42. Introduction to Digital Electronics. (3) Students will receive nor credit for 42 after taking 40 or 100. Three hours of lecture and one hour of discussion per week. *Prerequisites: Mathematics 1B.* This course serves as an introduction to the principles of electrical engineering, starting from the basic concepts of voltage and current and circuit elements of resistors, capacitors, and inductors. Circuit analysis is taught using Kirchhoff's voltage and current laws with Thevenin and Norton equivalents. Operational amplifiers with feedback are introduced as basic building blocks for amplication and filtering. Semiconductor devices including diodes and MOSFETS and their IV characteristics are covered. Applications of diodes for rectification, and design of MOSFETs in common source amplifiers are taught. Digital logic gates and design using CMOS as well as simple flip-flops are introduced. Speed and scaling issues for CMOS are considered. The course includes as motivating examples designs of high level applications including logic circuits, amplifiers, power supplies, and communication links. (F,SP) *Staff*

43. Introductory Electronics Laboratory. (1) Three hours of laboratory per week. Must be taken on a *passed/not passed* basis. *Prerequisites: 42 (may be taken concurrently) or equivalent or consent of instructor.* Using and understanding electronics laboratory equipment such as oscilloscope, power supplies, function generator, multimeter, curve-tracer, and RLC-meter. Includes a term project of constructing and testing a robot or other appropriate electromechanical device. (F,SP) *Staff*

84. Sophomore Seminar. (1,2) Course may be repeated for credit as topic varies. One hour of seminar per week per unit for fifteen weeks. One and one half hours of seminar per week per unit for 10 weeks. Two hours of seminar per week per unit for eight weeks. Three hours of seminar per week per unit for five weeks. Sections 1-2 to be graded on a *passed/not passed* basis. Sections 3-4 to be graded on a letter-grade basis. *Prerequisites: At discretion of instructor.* Sophomore seminars are small interactive courses offered by faculty members in departments all across the campus. Sophomore seminars offer opportunity for close, regular intellectual contact between faculty members and students in the crucial second year. The topics vary from department to department and semester to semester. Enrollment limited to 15 sophomores. (F,SP)

98. Directed Group Study for Undergraduates. (1-4) Course may be repeated for credit. Course format varies. Must be taken on a *passed/not passed* basis. Group study of selected topics in electrical engineering, usually relating to new developments. (F,SP) *Staff*

99. Individual Study and Research for Undergraduates. (1-4) Course may be repeated for credit. Enrollment is restricted; see the Introduction to Courses and Curricula section of this catalog. Must be taken on a *passed/not passed* basis. *Prerequisites: Freshman or sophomore standing and consent of instructor. Minimum GPA of 3.4 required.* Supervised independent study and research for students with fewer than 60 units completed. (F,SP) *Staff*

Electrical Engineering Upper Division Courses

100. Electronic Techniques for Engineering. (4) Students will receive one unit of credit for 100 after taking 42 and no credit after taking 40. Three hours of lecture, three hours of laboratory, and one hour of discussion per week. *Prerequisites: Mathematics 1B.*This course serves as an introduction to the principles of electrical engineering, starting from the basic concepts of voltage and current and circuit elements of resistors, capacitors, and inductors. Circuit analysis is taught using Kirchhoff's voltage and current laws with Thevenin and Norton equivalents. Operational amplifiers with feedback are introduced as basic building blocks for amplication and filtering. Semiconductor devices including diodes and MOSFETS and their IV characteristics are covered. Applications of diodes for rectification, and design of MOSFETs in common source amplifiers are taught. Digital logic gates and design using CMOS as well as simple flip-flops are introduced. Speed and scaling issues for CMOS are considered. The course includes as motivating examples designs of high level applications including logic circuits, amplifiers, power supplies, and communication links. (F,SP) *Staff*

105. Microelectronic Devices and Circuits. (4) Three hours of lecture, one hour of discussion, and three hours of laboratory per week. *Prerequisites: 40.* This course covers the fundamental circuit and device concepts needed to understand analog integrated circuits. After an overview of the basic properties of semiconductors, the p-n junction and MOS capacitors are described and the MOSFET is modeled as a large-signal device. Two port small-signal amplifiers and their realization using single stage and multistage CMOS building blocks are discussed. Sinusoidal steady-state signals are introduced and the techniques of phasor analysis are developed, including impedance and the magnitude and phase response of linear circuits. The frequency responses of single and multi-stage amplifiers are analyzed. Differential amplifiers are introduced. (F,SP) *Javey, Wu*

117. Electromagnetic Fields and Waves. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 40, Mathematics 53, 54, knowledge of phasor analysis (e.g. as taught in 105). Formerly 117A-117B.* Review of static electric and magnetic fields and applications; Maxwell's equations; transmission lines; propagation and reflection of plane waves; introduction to guided waves, microwave networks, and radiation and antennas. Minilabs on statics, transmission lines, and waves. (F,SP) *Staff*

118. Introduction to Optical Communication Systems and Networks. (3) Three hours of lecture per week. *Prerequisites: 20 and 40.* Basic principles of digital and analog optical communications and optical networks. Emphasis is on principles of optical links, including channel capacity, basic limitations due to noise processes, and bit error rate requirements. Optical amplification, the detector-receiver, optical fiber and free-space propagation, the transmitter, and modulation schemes. Coherent and incoherent communications and network systems. Basic optical Fourier transform signal processing techniques. (F) *Gustafson*

119. Introduction to Optical Engineering. (3) Three hours of lecture and one hour of discussion per week. *Prerequisites: Physics 7C.* Fundamental principles of optical systems. Geometrical optics and aberration theory. Stops and apertures, prisms, and mirrors. Diffraction and interference. Optical materials and coatings. Radiometry and photometry. Basic optical devices and the human eye. The design of optical systems. Lasers, fiber optics, and holography. (SP) *Bokor*

120. Signals and Systems. (4) Four hours of lecture and one hour of recitation per week. *Prerequisites: 20N, Mathematics 53, 54.* Continuous and discrete-time transform analysis techniques with illustrative applications. Linear and time-invariant systems, transfer functions. Fourier series, Fourier transform, Laplace and Z-transforms. Sampling and reconstruction. Solution of differential and difference equations using transforms. Frequency response, Bode plots, stability analysis. Illustrated by analysis of communication systems and feedback control systems. (F,SP) *Ramachandran, El-Ghaoui*

121. Introduction to Digital Communication Systems. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 120, 126.* Introduction to the basic principles of the design and analysis of modern digital communication systems. Topics include source coding, channel coding, baseband and passband modulation techniques, receiver design, and channel equalization. Applications to design of digital telephone modems, compact disks, and digital wireless communication systems. Concepts illustrated by a sequence of MATLAB exercises. (SP) *Tse*

122. Introduction to Communication Networks. (4) Three hours of lecture, one hour of discussion, and one hour of laboratory per week. *Prerequisites: Computer Science 61B, Mathematics 53 or 54.* This course is an introduction to the design and implementation of computer networks. We will focus on the concepts and fundamental design principles that have contributed to the Internet's scalability and robustness and survey the underlying technologies--e.g., Ethernet, 802.11, DSL, optical links--that have led to the Internet's phenomenal success. Topics include layering, congestion/flow/error control, routing, addressing, multicast, packet scheduling, switching, internetworking, network security, and networking/programming interfaces. (F,SP) *Parekh, Paxon*

123. Digital Signal Processing. (4) Three hours of lecture, one hour of discussion, and one hour of laboratory per week. *Prerequisites: 120.* Discrete time signals and systems: Fourier and Z transforms, DFT, 2-dimensional versions. Digital signal processing topics: flow graphs, realizations, FFT, chirp-Z algorithms, Hilbert transform relations, quantization effects, linear prediction. Digital filter design methods: windowing, frequency sampling, S-to-Z methods, frequency-transformation methods, optimization methods, 2-dimensional filter design. (SP) *Staff*

C125. Introduction to Robotics. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 120 or equivalent, consent of instructor.* An introduction to the kinematics, dynamics, and control of robot manipulators, robotic vision, sensing, and the programming of robots. The course will cover forward, inverse kinematics of serial chain manipulators. The manipulator Jacobian, force relations, dynamics and control-position, and force control. Trajectory generation, collision avoidance, automatic planning of fine and gross motion strategies, robot programming languages. Proximity, tactile, and force sensing. Network modeling, stability, and fidelity in teleoperation. Biological analogies and medical applications of robotics. Also listed as Bioengineering C125. (F,SP) *Tomlin*

126. Probability and Random Processes. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 20.* This course covers the fundamentals of probability and random processes useful in fields such as networks, communication, signal processing, and control. Sample space, events, probability law. Conditional probability. Independence. Random variables. Distribution, density functions. Random vectors. Law of large numbers. Central limit theorem. Estimation and detection. Markov chains. (F,SP) *Wainwright*

128. Feedback Control. (4) Three hours of lecture and three hours of laboratory per week. *Prerequisites: 120.* Analysis and synthesis of continuous and sampled-data linear feedback control systems. Advantages of feedback. Design by root locus, frequency response, and state space methods, with a comparison of techniques. Case studies. (F) *Carmena*

129. Neural and Nonlinear Information Processing. (3) Three hours of lecture per week. *Prerequisites: 120 or consent of instructor.* Principles of massively parallel real-time computation, optimization, and information processing via nonlinear dynamics and analog VLSI neural networks, applications selected from image processing, pattern recognition, feature extraction, motion detection, data compression, secure communication, bionic eye, auto waves, and Turing patterns. (SP) *Chua*

130. Integrated-Circuit Devices. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 40 or 100.* Overview of electronic properties of semiconductor. Metal-semiconductor contacts, pn junctions, bipolar transistors, and MOS field-effect transistors. Properties that are significant to device operation for integrated circuits. Silicon device fabrication technology. (F,SP) *Hu, King, Liu*

140. Linear Integrated Circuits. (4) Three hours of lecture and one hour of laboratory per week. *Prerequisites: 105.* Single and multiple stage transistor amplifiers. Operational amplifiers. Feedback amplifiers, 2-port formulation, source, load, and feedback network loading. Frequency response of cascaded amplifiers, gain-bandwidth exchange, compensation, dominant pole techniques, root locus. Supply and temperature independent biasing and references. Selected applications of analog circuits such as analog-to-digital converters, switched capacitor filters, and comparators. The laboratory builds on the concepts presented in the lectures and provides hands-on design experience and help with the use of computer aided design tools such as SPICE. (F,SP) *Alon, Sanders*

141. Introduction to Digital Integrated Circuits. (4) Three hours of lecture, one hour of discussion, and three hours of laboratory per week. *Prerequisites: 40; 105 and 150 recommended.* CMOS devices and deep sub-micron manufacturing technology. CMOS inverters and complex gates. Modeling of interconnect wires. Optimization of designs with respect to a number of metrics: cost, reliability, performance, and power dissipation. Sequential circuits, timing considerations, and clocking approaches. Design of large system blocks, including arithmetic, interconnect, memories, and programmable logic arrays. Introduction to design methodologies, including hands-on experience. (F,SP) *Alon, Rabaey*

142. Integrated Circuits for Communications. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 120 and 140.* Analysis and design of electronic circuits for communication systems, with an emphasis on integrated circuits for wireless communication systems. Analysis of distortion in amplifiers with application to radio receiver design. Power amplifier design with application to wireless radio transmitters. Class A, Class B, and Class C power amplifiers. Radio-frequency mixers, oscillators, phase-locked loops, modulators, and demodulators. (F) *Niknejad*

143. Microfabrication Technology. (4) Three hours of lecture and three hours of laboratory per week. *Prerequisites: 40 and Physics 7B.* Integrated circuit device fabrication and surface micromachining technology. Thermal oxidation, ion implantation, impurity diffusion, film deposition, expitaxy, lithography, etching, contacts and interconnections, and process integration issues. Device design and mask layout, relation between physical structure and electrical/mechanical performance. MOS transistors and poly-Si surface microstructures will be fabricated in the laboratory and evaluated. (F,SP) *Subramanian*

C145B. Image Processing and Reconstruction Tomography. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 120; basic programming ability in C or FORTRAN.* Linear systems and Fourier transforms in two and three dimensions. Basic image processing. Theory and algorithms for image reconstruction from projections. Physics of imaging systems including magnetic resonance, X-ray tomography, positron emission tomography, ultrasound, and biomagnetic imaging. Data analysis including hypothesis testing, parameter estimation by least squares, and compartmental kinetic modeling. Field trips to medical imaging laboratories. Also listed as Bioengineering C165. (SP) *Conolly*

145L. Introductory Electronic Transducer Laboratory. (3) Two hours of lecture and three hours of laboratory per week. *Prerequisites: 40.* Laboratory exercises exploring a variety of electronic transducers for measuring physical quantities such as temperature, force, displacement, sound, light, ionic potential; the use of circuits for low-level differential amplification and analog signal processing; and the use of microcomputers for digital sampling and display. Lectures cover principles explored in the laboratory exercises; construction, response and signal to noise of electronic transducers and actuators; and design of circuits for sensing and controlling physical quantities. (F) *Derenzo*

C145L. Introductory Electronic Transducers Laboratory. (3) Two hours of lecture and three hours of laboratory per week. *Prerequisites: 40.* Laboratory exercises exploring a variety of electronic transducers for measuring physical quantities such as temperature, force, displacement, sound, light, ionic potential; the use of circuits for low-level differential amplification and analog signal processing; and the use of microcomputers for digital sampling and display. Lectures cover principles explored in the laboratory exercises; construction, response and signal to noise of electronic transducers and actuators; and design of circuits for sensing and controlling physical quantities. Also listed as Bioengineering C145L. (F) *Derenzo*

145M. Introductory Microcomputer Interfacing Laboratory. (3) Two hours of lecture and three hours of laboratory per week. *Prerequisites: 40 and 60B.* Laboratory exercises constructing basic interfacing circuits and writing 20-100 line C programs for data acquisition, storage, analysis, display, and control. Use of the IBM PC with microprogrammable digital counter/timer, parallel I/O port, and analog I/O port. Circuit components include anti-aliasing filters, the S/H amplifier, A/D and D/A converters. Exercises include effects of aliasing in periodic sampling, fast Fourier transforms of basic waveforms, the use of the Hanning filter for leakage reduction, Fourier analysis of the human voice, digital filters, and control using Fourier deconvolution. Lectures cover principles explored in the laboratory exercises and design of microcomputer-based systems for data acquisition, analysis, and control. (SP) *Derenzo*

C145M. Introductory Microcomputer Interfacing Laboratory. (3) Two hours of lecture and three hours of laboratory per week. *Prerequisites: 40, Computer Science 61B or a working knowledge of ANSI C programming or consent of instructor.* Laboratory exercises constructing basic interfacing circuits and writing 20-100 line C programs for data acquisition, storage, analysis, display, and control. Use of the IBM PC with microprogrammable digital counter/timer, parallel I/O port. Circuit components include anti-aliasing filters, the S/H amplifier, A/D and D/A converters. Exercises include effects of aliasing in periodic sampling, fast Fourier transforms of basic waveforms, the use of the Hanning filter for leakage reduction, Fourier analysis of the human voice, digital filters, and control using Fourier deconvolution. Lectures cover principles explored in the lab exercises and design of microcomputer-based systems for data acquisitions, analysis and control. Also listed as Bioengineering C145M. (F) *Derenzo*

192. Mechatronic Design Laboratory. (4) One and one-half hours of lecture and ten hours of laboratory per week. *Prerequisites: 120, Computer Science 61B or 61C, 150 or equivalent.* Design project course, focusing on application of theoretical principles in electrical engineering to control of a small-scale system, such as a mobile robot. Small teams of students will design and construct a mechatronic system incorporating sensors, actuators, and intelligence. (SP) *Fearing*

H196A-H196B. Senior Honors Thesis Research. (4;4) Individual research. *Prerequisites: Open only to students in the electrical engineering honors program.* Thesis work under the supervision of a faculty member. To obtain credit the student must, at the end of two semesters, submit a satisfactory thesis to the Electrical Engineering and Computer Science department archive. A total of four units must be taken. The units may be distributed between one or two semesters in any way. H196A-H196B count as graded technical elective units, but may not be used to satisfy the requirement for 20 upper division technical units in EECS. (F,SP) *Staff*

198. Directed Group Study for Advanced Undergraduates. (1-4) Course may be repeated for credit. To vary with section. Must be taken on a *passed/not passed* basis. *Prerequisites: 2.0 GPA or better; 60 units completed.* Group study of selected topics in electrical engineering, usually relating to new developments. (F,SP) *Staff*

199. Supervised Independent Study. (1-4) Enrollment is restricted; see the Introduction to Courses and Curricula section of this catalog. Individual conferences. Must be taken on a *passed/not passed* basis. *Prerequisites: Consent of instructor and major adviser.* Supervised independent study. Enrollment restrictions apply. (F,SP) *Staff*

Electrical Engineering Graduate Courses

C201. Strategic Computing and Communications Technology. (3) Three hours of lecture per week. *Prerequisites: Graduate standing in engineering, business administration, information management and systems, or consent of instructor.* Factors strongly impacting the success of new computing and communications products and services (based on underlying technologies such as electronics and software) in commercial applications. Technology trends and limits, economics, standardization, intellectual property, government policy, and industrial organization. Strategies to manage the design and marketing of successful products and services. Also listed as Information C224. (F,SP) *Staff*

210. Applied Electromagnetic Theory. (3) Three hours of lecture per week. *Prerequisites: 117, or Physics 110A, 110B. Formerly 210A-210B.* Advanced treatment of classical electromagnetic theory with engineering applications. Boundary value problems in electrostatics. Applications of Maxwell's Equations to the study of waveguides, resonant cavities, optical fiber guides, Gaussian optics, diffraction, scattering, and antennas. (F) *Welch*

C213. Soft X-rays and Extreme Ultraviolet Radiation. (3) Three hours of lecture per week. *Prerequisites: Physics 110, 137, and Mathematics 53, 54 or equivalent. Formerly El Engineering 290G.* This course will explore modern developments in the physics and applications of soft x-rays. It begins with a review of electromagnetic radiation at short wavelengths including dipole radiation, scattering and refractive index, using a semi-classical atomic model. Subject matter will include the generation of x-rays with laboratory tubes, synchrotron radiation, laser-plasma sources, x-ray lasers, and black body radiation. Concepts of spatial and temporal coherence will be discussed. Also listed as Applied Science and Technology C210. (SP) *Attwood*

216. Antennas and Propagation. (3) Three hours of lecture per week. *Prerequisites: 210 or consent of instructor.* Application of Maxwell's Equations to the study of antennas and the propagation of electromagnetic waves. Basic concepts of antennas as devices in communication systems. Analysis of wire antennas, arrays of elements, horns, reflector and lens systems, frequency independent antennas. The propagation of waves over the earth and in inhomogeneous and random media. Offered alternate years. (SP) *Staff*

217. Microwave Circuits. (3) Three hours of lecture per week. *Prerequisites: 117 and 140 or equivalent.* Techniques of analog circuit technology in the high-frequency regime above 1 GHz. Transmission lines and distributed circuit elements; S-parameter design of high-frequency active circuits; computer-aided analysis and design. Emphasis on design of planar high-frequency integrated circuits employing CMOS and SiGe technology. Circuit building blocks for broadband wired and wireless communication will be emphasized including oscillators, low-noise amplifiers, and power amplifiers. Offered alternate years. (SP) *Niknejad*

219A. Computer-Aided Verification of Electronic Circuits and Systems. (3) Three hours of lecture per week. *Prerequisites: Consent of instructor; a course in linear algebra and on circuits is very useful. Formerly 219.* This course deals with techniques for the verification of correct behavior of complex electronic circuits and systems including algorithms and systems for the detailed simulation of integrated circuits at the transistor level in the time and frequency domain, discrete-event logic simulation, cycle-based logic simulation, RTL and behavioral simulation, equivalence checking, timing analysis, and power estimation. (F,SP) *Staff*

219B. Logic Synthesis. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: Consent of instructor.* The course covers the fundamental techniques for the design and analysis of digital circuits. The goal is to provide a detailed understanding of basic logic synthesis and analysis algorithms, and to enable students to apply this knowledge in the design of digital systems and EDA tools. The course will present combinational circuit optimization (two-level and multi-level synthesis), sequential circuit optimization (state encoding, retiming), timing analysis, testing, and logic verification. (F,SP) *Staff*

219C. Computer-Aided Verification. (3) Three hours of lecture per week. *Prerequisites: Consent of instructor; Computer Science 170 is recommended.* Introduction to the theory and practice of formal methods for the design and analysis of systems, with a focus on automated algorithmic techniques. Covers selected topics in computational logic and automata theory including formal models of reactive systems, temporal logic, model checking, and automated theorem proving. Applications in hardware and software verification, analysis of embedded, real-time, and hybrid systems, computer security, synthesis, planning, constraint solving, and other areas will be explored as time permits. Offered alternate years. (F,SP) *Seshia*

220. Nonlinear Circuits. (3) Three hours of lecture per week. *Prerequisites: 104.* Algebraic and dynamic n-ports. Potential and state functions. Volterra series. Frequency-power formulas. Qualitative properties: equilibrium states, stability, oscillations, subharmonic, almost-periodic, and chaotic phenomenon. Frequency entrainment. Harmonic balance, describing function and bifurcation. Applications to oscillators, multivibrators, mixers, modulators and harmonic generators. Offered alternate years. (SP) *Chua*

221A. Linear System Theory. (4) Three hours of lecture and two hours of recitation per week. *Prerequisites: 120; Mathematics 110 recommended.* Basic system concepts; state-space and I/O representation. Properties of linear systems. Controllability, observability, minimality, state and output-feedback. Stability. Observers. Characteristic polynomial. Nyquist test. (F,SP) *Staff*

222. Nonlinear Systems--Analysis, Stability and Control. (3) Three hours of lecture per week. *Prerequisites: 221A (may be taken concurrently).* Basic graduate course in non-linear systems. Second Order systems. Numerical solution methods, the describing function method, linearization. Stability - direct and indirect methods of Lyapunov. Applications to the Lure problem - Popov, circle criterion. Input-Output stability. Additional topics include: bifurcations of dynamical systems, introduction to the "geometric" theory of control for nonlinear systems, passivity concepts and dissipative dynamical systems. (SP) *Sastry*

223. Stochastic Systems: Estimation and Control. (3) Three hours of lecture per week. *Prerequisites: 226A (which students are encouraged to take concurrently).* Parameter and state estimation. System identification. Nonlinear filtering. Stochastic control. Adaptive control. (SP) *Staff*

224A. Digital Communications. (4) Four hours of lecture and one hour of discussion per week. *Prerequisites: 120 and 126, or equivalent. Formerly 224.* Introduction to the basic principles of the design and analysis of modern digital communication systems. Topics include source coding; channel coding; baseband and passband modulation techniques; receiver design; channel equalization; information theoretic techniques; block, convolutional, and trellis coding techniques; multiuser communications and spread spectrum; multi-carrier techniques and FDM; carrier and symbol synchronization. Applications to design of digital telephone modems, compact disks, and digital wireless communication systems are illustrated. The concepts are illustrated by a sequence of MATLAB exercises. (F,SP) *Staff*

224B. Fundamentals of Wireless Communication. (3) Three hours of lecture per week. *Prerequisites: 121, 226A, or equivalent.* Introduction of the fundamentals of wireless communication. Modeling of the wireless multipath fading channel and its basic physical parameters. Coherent and noncoherent reception. Diversity techniques over time, frequency, and space. Spread spectrum communication. Multiple access and interference management in wireless networks. Frequency re-use, sectorization. Multiple access techniques: TDMA, CDMA, OFDM. Capacity of wireless channels. Opportunistic communication. Multiple antenna systems: spatial multiplexing, space-time codes. Examples from existing wireless standards. (SP) *Tse*

225A. Digital Signal Processing. (3) Three hours of lecture per week. *Prerequisites: 123 and 126 or solid background in stochastic processes.* Advanced techniques in signal processing. Stochastic signal processing, parametric statistical signal models, and adaptive filterings. Application to spectral estimation, speech and audio coding, adaptive equalization, noise cancellation, echo cancellation, and linear prediction. (SP) *Gastpar*

225B. Digital Image Processing. (3) Three hours of lecture per week. *Prerequisites: 123.* 2-D sequences and systems, separable systems, projection slice thm, reconstruction from projections and partial Fourier information, Z transform, different equations, recursive computability, 2D DFT and FFT, 2D FIR filter design; human eye, perception, psychophysical vision properties, photometry and colorimetry, optics and image systems; image enhancement, image restoration, geometrical image modification, morphological image processing, halftoning, edge detection, image compression: scalar quantization, lossless coding, huffman coding, arithmetic coding dictionary techniques, waveform and transform coding DCT, KLT, Hadammard, multiresolution coding pyramid, subband coding, Fractal coding, vector quantization, motion estimation and compensation, standards: JPEG, MPEG, H.xxx, pre- and post-processing, scalable image and video coding, image and video communication over noisy channels. (F,SP) *Zakhor*

225C. VLSI Signal Processing. (3) Three hours of lecture per week. *Prerequisites: 141, 123. Formerly 290M*. Design of signal processing systems. Building blocks and design styles. Simulation and specification. Architectural trade-offs. Synthesis techniques. (SP) *Broderson, Rabaey*

225D. Audio Signal Processing in Humans and Machines. (3) Three hours of lecture per week. *Prerequisites: 123 or equivalent; Statistics 200A or equivalent; or graduate standing and consent of instructor.* Introduction to relevant signal processing and basics of pattern recognition. Introduction to coding, synthesis, and recognition. Models of speech and music production and perception. Signal processing for speech analysis. Pitch perception and auditory spectral analysis with applications to speech and music. Vocoders and music synthesizers. Statistical speech recognition, including introduction to Hidden Markov Model and Neural Network approaches. (SP) *Broderson, Morgan*

226A. Random Processes in Systems. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 120 and Statistics 200A or equivalent. Formerly 226.* Probability, random variables and their convergence, random processes. Filtering of wide sense stationary processes, spectral density, Wiener and Kalman filters. Markov processes and Markov chains. Gaussian, birth and death, poisson and shot noise processes. Elementary queuing analysis. Detection of signals in Gaussian and shot noise, elementary parameter estimation. (F) *Anantharam, Varaiya*

227A. Introduction to Convex Optimization. (3) Three hours of lecture per week. Convex optimization is a class of nonlinear optimization problems where the objective to be minimized, and the constraints, are both convex. Contrarily to the more classical linear programming framework, convex programs often go unrecognized, and this is a pity since a large class of convex optimization problems can now be efficiently solved. In addition, it is possible to address hard, nonconvex problems (such as "combinatorial optimization" problems) using convex approximations that are more efficient than classical linear ones. The 3-unit course covers some convex optimization theory and algorithms, and describes various applications arising in engineering design, modeling and estimation, finance, and operations research. (F) *El-Ghaoui*

227B. Convex Optimization and Approximation. (3) Three hours of lecture per week. *Prerequisites: 227A or consent of instructor.* Convex optimization as a systematic approximation tool for hard decision problems. Approximations of combinatorial optimization problems, of stochastic programming problems, of robust optimization problems (i.e., with optimization problems with unknown but bounded data), of optimal control problems. Quality estimates of the resulting approximation. Applications in robust engineering design, statistics, control, finance, data mining, operations research. (F) *El-Ghaoui*

228A. High Speed Communications Networks. (3) Three hours of lecture per week. *Prerequisites: 122, 226A (may be taken concurrently).* Descriptions, models, and approaches to the design and management of networks. Optical transmission and switching technologies are described and analyzed using deterministic, stochastic, and simulation models. FDDI, DQDB, SMDS, Frame Relay, ATM, networks, and SONET. Applications demanding high-speed communication. (F) *Varaiya, Walrand*

229. Information Theory and Coding. (3) Three hours of lecture per week. *Prerequisites: 226 recommended, Statistics 200A or equivalent. Formerly EECS 229B* Fundamental bounds of Shannon theory and their application. Source and channel coding theorems. Galois field theory, algebraic error-correction codes. Private and public-key cryptographic systems. Offered alternate years. (SP) *Anantharam*

229A. Information Theory and Coding. (3) Three hours of lecture per week. *Prerequisites: 226 recommended, Statistics 200A or equivalent. Formerly 229.* Fundamental bounds of Shannon theory and their application. Source and channel coding theorems. Galois field theory, algebraic error-correction codes. Private and public-key cryptographic systems. Offered alternate years. (SP) *Anantharam*

229B. Error Control Coding. (3) Three hours of lecture per week. *Prerequisites: 126 or equivalent (some familiarity with basic probability). Prior exposure to information theory not necessary.* Error control codes are an integral part of most communication and recording systems where they are primarily used to provide resiliency to noise. In this course, we will cover the basics of error control coding for reliable digital transmission and storage. We will discuss the major classes of codes that are important in practice, including Reed Muller codes, cyclic codes, Reed Solomon codes, convolutional codes, concatenated codes, turbo codes, and low density parity check codes. The relevant background material from finite field and polynomial algebra will be developed as part of the course. Overview of topics: binary linear block codes; Reed Muller codes; Galois fields; linear block codes over a finite field; cyclic codes; BCH and Reed Solomon codes; convolutional codes and trellis based decoding, message passing decoding algorithms; trellis based soft decision decoding of block codes; turbo codes; low density parity check codes. (SP) *Anatharam*

230. Solid State Electronics. (3) Three hours of lecture per week. *Prerequisites: 131; Physics 137B.* Crystal structure and symmetries. Energy-band theory. Cyclotron resonance. Tensor effective mass. Statistics of electronic state population. Recombination theory. Carrier transport theory. Interface properties. Optical processes and properties. (F,SP) *Gustafson*

231. Solid State Devices. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 130 or equivalent.* Physical principles and operational characteristics of semiconductor devices. Emphasis is on MOS field-effect transistors and their behaviors dictated by present and probable future technologies. Metal-oxide-semiconductor systems, short-channel and high field effects, device modeling, and impact on analog, digital circuits. (SP) *Javey, King, Liu*

232. Lightwave Devices. (3) Three hours of lecture per week. *Prerequisites: 136 or equivalent; background in semiconductor physics.* Principle of semiconductor lasers. Modulation dynamics. Single frequency lasers. Fundamental AM and FM noise properties, linewidth. Tunable semiconductor lasers. Quantum well lasers. Electrooptic modulators and switches. Detectors. Integrated optoelectronic circuits. Optical amplifiers-semiconductor and Erbium fiber. Low coherence sources-superluminescent diodes. Tunable optical filters. (F) *Wu*

233. Lightwave Systems. (3) Three hours of lecture per week. *Prerequisites: 120 and 121 or equivalent; 136 recommended.* Transmission properties of optical fibers - dispersion, attenuation, nonlinear effects (solitons). Direct-detection systems: analog and digital modulation, transmitter design, receiver design, noise properties of single and multimode fiber links, dependence on source coherence, subcarrier and multichannel CATV analog transmission issues the role of optical fiber amplifiers. Coherent communication: FM noise and modulation properties of laser diodes, quantum limited detection, homodyne and heterodyne detection of various formats, laser linewidth requirements, diversity issues. Lightwave networks - WDMA, FDMA, subcarrier, TDMA, and CDMA, relative merits. Topological issues - multihop (sore-and-forward) and hot-potato routing, the role of optical switching. Optical network access protocols. Optical interconnection in high speed circuit modules and computers. (SP) *Ivan*

C235. Nanoscale Fabrication. (4) Three hours of lecture and one hour of discussion per week. This course discusses various top-down and bottom-up approaches to synthesizing and processing nanostructured materials. The topics include fundamentals of self assembly, nano-imprint lithography, electron beam lithography, nanowire and nanotube synthesis, quantum dot synthesis (strain patterned and colloidal), postsynthesis modification (oxidation, doping, diffusion, surface interactions, and etching techniques). In addition, techniques to bridging length scales such as heterogeneous integration will be discussed. We will discuss new electronic, optical, thermal, mechanical, and chemical properties brought forth by the very small sizes. Also listed as Nanoscale Science and Engineering C203. (F) *Chang-Hasnain*

236A. Quantum and Optical Electronics. (3) Three hours of lecture per week. *Prerequisites: 117A, Physics 137A or equivalent.* Interaction of radiation with atomic and semiconductor systems, density matrix treatment, semiclassical laser theory (Lamb's), laser resonators, specific laser systems, laser dynamics, Q-switching and mode-locking, noise in lasers and optical amplifiers. Nonlinear optics, phase-conjugation, electrooptics, acoustooptics and magnetooptics, coherent optics, stimulated Raman and Brillouin scattering. Offered alternate years. (F,SP) *Gustafson*

238. Superconductive Devices and Circuits. (3) Three hours of lecture per week. *Prerequisites: 117A,131; Physics 137A.* Introduction to superconductivity. Electron pairing. BCS and Ginzburg-Landau theories. Single-particle and Josephson tunneling. Electrodynamics of superconductors and Josephson junctions. Proximity effect. Mixed state in type II superconductors. Thin films. Applications in analog and digital circuits. Fabrication technology. *Van Duzer*

C239. Partially Ionized Plasmas. (3) Three hours of lecture per week. *Prerequisites: Upper division course in electromagnetics or fluid dynamics. Formerly 239.*Introduction to partially ionized, chemically reactive plasmas, including collisional processes, diffusion, sources, sheaths, boundaries, and diagnostics. DC, RF, and microwave discharges. Applications to plasma-assisted materials processing and to plasma wall interactions. Also listed as Applied Science and Technology C239. Offered alternate years. (SP) *Lieberman*

240. Advanced Analog Integrated Circuits. (3) Three hours of lecture per week. *Prerequisites: 140.* Analysis and optimized design of monolithic operational amplifiers and wide-band amplifiers; methods of achieving wide-band amplification, gain-bandwidth considerations; analysis of noise in integrated circuits and low noise design. Precision passive elements, analog switches, amplifiers and comparators, voltage reference in NMOS and CMOS circuits, Serial, successive-approximation, and parallel analog-to-digital converters. Switched-capacitor and CCD filters. Applications to codecs, modems. (F,SP) *Boser*

241. Advanced Digital Integrated Circuits. (3) Three hours of lecture per week. *Prerequisites: 141.* Analysis and design of MOS and bipolar large-scale integrated circuits at the circuit level. Fabrication processes, device characteristics, parasitic effects static and dynamic digital circuits for logic and memory functions. Calculation of speed and power consumption from layout and fabrication parameters. ROM, RAM, EEPROM circuit design. Use of SPICE and other computer aids. (SP) *Nikolic, Rabaey*

242. Advanced Integrated Circuits for Communications. (3) Three hours of lecture per week. *Prerequisites: 142, 240.* Analysis, evaluation and design of present-day integrated circuits for communications application, particularly those for which nonlinear response must be included. MOS, bipolar and BICMOS circuits, audio and video power amplifiers, optimum performance of near-sinusoidal oscillators and frequency-translation circuits. Phase-locked loop ICs, analog multipliers and voltage-controlled oscillators; advanced components for telecommunication circuits. Use of new CAD tools and systems. (F,SP) *Meyer, Niknejad*

243. Advanced IC Processing and Layout. (3) Three hours of lecture per week. *Prerequisites: 143 and either 140 or 141.* The key processes for the fabrication of integrated circuits. Optical, X-ray, and e-beam lithography, ion implantation, oxidation and diffusion. Thin film deposition. Wet and dry etching and ion milling. Effect of phase and defect equilibria on process control. (SP) *Staff*

244. Computer-Aided Design of Integrated Circuits. (3) Three hours of lecture per week. *Prerequisites: 140 or 141.* This course will cover a wide variety of topics relating to the development of computer aids for integrated circuit design. The course will emphasize state-of-the-art techniques and both the theoretical basis for the methods as well as the application of results to practical problems, including details of implementation. Topics to be covered include simulation, layout techniques, synthesis, verification, testing, and integrated design systems. (F) *Keutzer*

C245. Introduction to MEMS Design. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: Graduate standing in engineering or science; undergraduates with consent of instructor.* Physics, fabrication, and design of micro-electromechanical systems (MEMS). Micro- and nano-fabrication processes, including silicon surface and bulk micromachining and non-silicon micromachining. Integration strategies and assembly processes. Microsensor and microactuator devices: electrostatic, piezoresistive, piezoelectric, thermal, magnetic transduction. Electronic position-sensing circuits and electrical and mechanical noise. CAD for MEMS. Design project is required. Also listed as Mechanical Engineering C218. (F,SP) *Staff*

C246. Microelectromechanical Systems (MEMS). (3) Three hours of lecture per week. *Prerequisites: Graduate standing or consent of instructor.* This course is aimed to provide basic understanding of integrated circuit (IC) processes and microelectromechanical system (MEMS). Technologies including analyses, design, and manufacturing processes of MEMS will be introduced. The first part of the course emphasizes IC processes including thin film deposition, lithography, and etching. The second part of the course deals with micromachining processes including surface-, bulk-micromachining, LIGA and other processes. Also listed as Mechanical Engineering C219. (SP) *Pisano*

247. Analysis and Design of VLSI Analog-Digital Interface Integrated Circuits. (3) Three hours of lecture per week. *Prerequisites: 240.* Architectural and circuit level design and analysis of integrated analog-to-digital and digital-to-analog interfaces in CMOS and BiCMOS VLSI technology. Analog-digital converters, digital-analog converters, sample/hold amplifiers, continuous and switched-capacitor filters. RF integrated electronics including synthesizers, LNA's, and baseband processing. Low power mixed signal design. Data communications functions including clock recovery. CAD tools for analog design including simulation and synthesis. *Khorramabadi*

249. Embedded System Design: Models, Validation, and Synthesis. (4) Four hours of lecture and two hours of laboratory/discussion per week. *Prerequisites: Background in SoC design, operating systems and compilers, or consent of instructor.* Principles of embedded system design. Focus on design methodologies and foundations. Platform-based design and communication-based design and their relationship with design time, re-use, and performance. Models of computation and their use in design capture, manipulation, verification, and synthesis. Mapping into architecture and system platforms. Performance estimation. Scheduling and real-time requirements. Synchronous languages and time-triggered protocols to simplify the design process. Simulation techniques for highly programmable platforms. Synthesis and successive refinement: meta-model of computation. Use of design tools and analysis of their capabilities and limitations: Ptolemy, POLIS, Metropolis, VCC, Co-ware. (F) *Sangiovanni-Vincentelli*

290. Advanced Topics in Electrical Engineering. Course may be repeated for credit. One to three hours of lecture per week. *Prerequisites: Consent of instructor.* The 290 courses cover current topics of research interest in electrical engineering. The course content may vary from semester to semester.

290A. Advanced Topics in Computer-Aided Design. (1-3)

290B. Advanced Topics in Solid State Devices. (1-3)

290C. Advanced Topics in Circuit Design. (1-3)

290D. Advanced Topics in Semiconductor Technology. (1-3)

290E. Advanced Topics in Electromagnetics and Plasmas. (1-3)

290F. Advanced Topics in Photonics. (1-3)

290G. Advanced Topics in Mems, Microsensors, and Microactuators. (1-3)

290H. Advanced Topics in Semiconductor Manufacturing. (1-3)

290K. Advanced Topics in Optimization. (1-3)

290N. Advanced Topics in System Theory. (1-3)

290O. Advanced Topics in Control. (1-3)

290P. Advanced Topics in Bioelectronics. (1-3)

290Q. Advanced Topics in Communication Networks. (1-3)

290S. Advanced Topics in Communications and Information Theory. (1-3)

290T. Advanced Topics in Signal Processing. (1-3)

290X. Advanced Topics in Management and Social Issues in Electrical Engineering and Computer Sciences. (1-3)

290Y. Organic Materials in Electronics. (3) *Prerequisites: 130; undergraduate general chemistry.* Organic materials are seeing increasing application in electronics applications. This course will provide an overview of the properties of the major classes of organic materials with relevance to electronics. Students will study the technology, physics, and chemistry of their use in the three most rapidly growing major applications--energy conversion/generation devices (fuel cells and photovoltaics), organic light-emitting diodes, and organic transistors. (F,SP) *Subramanian*

C291. Control and Optimization of Distributed Parameters Systems. (3) Three hours of lecture per week. Distributed systems and PDE models of physical phenomena (propagation of waves, network traffic, water distribution, fluid mechanics, electromagnetism, blood vessels, beams, road pavement, structures, etc.). Fundamental solution methods for PDEs: separation of variables, self-similar solutions, characteristics, numerical methods, spectral methods. Stability analysis. Adjoint-based optimization. Lyapunov stabilization. Differential flatness. Viability control. Hamilton-Jacobi-based control. Also listed as Civil and Environmental Engineering C291F and Mechanical Engineering C236. (SP) *Bayen*

C291E. Hybrid Systems and Intelligent Control. (3) Three hours of lecture per week. *Formerly 291E.* Analysis of hybrid systems formed by the interaction of continuous time dynamics and discrete-event controllers. Discrete-event systems models and language descriptions. Finite-state machines and automata. Model verification and control of hybrid systems. Signal-to-symbol conversion and logic controllers. Adaptive, neural, and fuzzy-control systems. Applications to robotics and Intelligent Vehicle and Highway Systems (IVHS). Also listed as Mechanical Engineering C290S. *Hedrick*

297. Field Studies in Electrical Engineering. (1-12) Course may be repeated for credit. Individual conferences. Must be taken on a *satisfactory/unsatisfactory* basis. Supervised experience in off-campus companies relevant to specific aspects and applications of electrical engineering. Written report required at the end of the semester. (F,SP) *Pister*

298. Group Studies, Seminars, or Group Research. (1-4) Course may be repeated for credit. One to four hours of lectures per unit. Section 1-40 to be graded on a *satisfactory/unsatisfactory* basis. Sections 41-49 to be graded on a letter-grade basis. Advanced study in various subjects through special seminars on topics to be selected each year, informal group studies of special problems, group participation in comprehensive design problems, or group research on complete problems for analysis and experimentation. (F,SP) *Staff*

299. Individual Research. (1-12) Course may be repeated for credit. Independent, individual study or investigation. Investigation of problems in electrical engineering. (F,SP) *Staff*

602. Individual Study for Doctoral Students. (1-8) Course may be repeated for credit. Course does not satisfy unit or residence requirements for doctoral degree. Independent study, in consultation with faculty member. Must be taken on a *satisfactory/unsatisfactory* basis. Individual study in consultation with the major field adviser, intended to provide an opportunity for qualified students to prepare themselves for the various examinations required of candidates for the Ph.D. (and other doctoral degrees). (F,SP) *Staff*

Electrical Engineering Professional Courses

301. Teaching Techniques for Electrical Engineering. (1) One and one-half hours of seminar per week. Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisites: Graduate standing.* Weekly seminars and discussions of effective teaching techniques. Use of educational objectives, alternative forms of instruction, and special techniques for teaching key concepts and techniques in electrical engineering. Student and self-evaluation. Course is intended to orient new graduate student instructors to teaching in the Electrical Engineering Department at Berkeley. (F) *Staff*

6.1.2 Computer Science

Computer Science Lower Division Courses

3. Introduction to Symbolic Programming. (4) Refer to computer science service course restrictions. Two hours of lecture, one hour of discussion, and two hours of scheduled programming laboratory per week. *Prerequisites: High school algebra.* Introduction to computer programming, emphasizing symbolic computation and functional programming style. Students will write a project of at least 200 lines of code, using the Scheme programming language. (F,SP) *Clancy*

3L. Introduction to Symbolic Programming. (4) One hour of lecture and six hours of laboratory per week and approximately five hours of self-scheduled programming laboratory. *Prerequisites: High school algebra.* Introduction to computer programming, emphasizing symbolic computation and functional programming style. Students will write a project of at least 200 lines of code in Scheme (a dialect of the LISP programming language). (F,SP) *Clancy*

3S. Introduction to Symbolic Programming (Self-Paced). (1-4) Refer to computer science service course restrictions. Course may be repeated up to 4 units. One to four hours of discussion and three to nine hours of laboratory per week. *Prerequisites: High school algebra.* The same material as 3 but in a self-paced format; introduction to computer programming, emphasizing symbolic computation and functional programming style, using the Scheme programming language. Units assigned depend on amount of work completed. The first two units must be taken together. (F,SP) *Clancy, Garcia*

9A. Matlab for Programmers. (1) Refer to computer science service course restrictions. Self-paced. Must be taken on a *passed/not passed* basis. *Prerequisites: Programming experience equivalent to that gained in 4; familiarity with applications of matrix processing.* Introduction to the constructs in the Matlab programming language, aimed at students who already know how to program. Array and matrix operations, functions and function handles, control flow, plotting and image manipulation, cell arrays and structures, and the Symbolic Mathematics toolbox. (F,SP) *Clancy, Garcia*

9B. Pascal for Programmers. (1) Refer to computer science service course restrictions. Self-paced. Must be taken on a *passed/not passed* basis. *Prerequisites: Programming experience similar to that gained in 3 or 77.* Self-paced Pascal course for students who already know how to program. This course provides the practice with the use of pointers and linked data structures that is assumed as prerequisite for 9C and 9F. (F,SP) *Clancy, Garcia*

9C. C for Programmers. (1) Refer to computer science service course restrictions. Must be taken on a *passed/not passed* basis. *Prerequisites: Programming experience with pointers (or addresses in assembly language) and linked data structures equivalent to that gained in 9B, 61A, or Engineering 77.* Self-paced course in the C programming language for students who already know how to program. Computation, input and output, flow of control, functions, arrays, and pointers, linked structures, use of dynamic storage, and implementation of abstract data types. (F,SP) *Clancy, Garcia*

9D. Scheme and Functional Programming for Programmers. (1) Refer to computer science service course restrictions. Must be taken on a *passed/not passed* basis. *Prerequisites: Programming experience similar to that gained in Engineering 77.* Self-paced course in functional programming, using the Scheme programming language, for students who already know how to program. Recursion; higher-order functions; list processing; implementation of rule-based querying. (F,SP) *Clancy, Garcia*

9E. Productive Use of the UNIX Environment. (1) Refer to computer science service course restrictions. Self-paced. Must be taken on a *passed/not passed* basis. *Prerequisites: Programming experience similar to that gained in 61A or Engineering 77; DOS or UNIX experience.* Use of UNIX utilities and scripting facilities for customizing the programming environment, organizing files (possibly in more than one computer account), implementing a personal database, reformatting text, and searching for online resources. (F,SP) *Clancy, Garcia*

9F. C++ for Programmers. (1) Refer to computer science service course restrictions in the *General Catalog*. Must be taken on a *passed/not passed* basis. *Prerequisites: Programming experience equivalent to that gained in 9B, 61A, or Engineering 77.* Self-paced introduction to the constructs provided in the C++ programming language for procedural and object-oriented programming, aimed at students who already know how to program. (F,SP) *Clancy, Garcia*

9G. JAVA for Programmers. (1) One hour of self-paced per week. Must be taken on a *passed/not passed* basis. *Prerequisites: 9C or 9F or 61A plus experience with object-oriented programming or C-based language.* Self-paced course in Java for students who already know how to program. Applets; variables and computation; events and flow of control; classes and objects; inheritance; GUI elements; applications; arrays, strings, files, and linked structures; exceptions; threads. (F,SP) *Clancy, Garcia*

9H. Python for Programmers. (1) Refer to computer science service course restrictions. Self-paced. Must be taken on a *passed/not passed* basis. *Prerequisites: Programming experience equivalent to that gained in 3 or 4.* Introduction to the constraints provided in the Python programming language, aimed at students who already know how to program. Flow of control; strings, tuples, lists, and dictionaries; CGI programming; file input and output; object-oriented programming; GUI elements. (F,SP) *Clancy, Garcia*

24. Freshman Seminars. (1) Course may be repeated for credit as topic varies. One hour of seminar per week. Sections 1-2 to be graded on a letter-grade basis. Sections 3-4 to be graded on a *passed/not passed* basis. The Freshman Seminar Program has been designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small-seminar setting. Freshman seminars are offered in all campus departments, and topics vary from department to department and semester to semester. Enrollment limited to 15 freshmen. (F,SP)

39J. Freshman/Sophomore Seminar. (2-4) Course may be repeated for credit as topic varies. Two to four hours of seminar per week. Sections 1-2 to be graded on a letter-grade basis. Sections 3-4 to be graded on a *passed/not passed* basis. *Prerequisites: Priority given to freshmen and sophomores.* Freshman and sophomore seminars offer lower division students the opportunity to explore an intellectual topic with a faculty member and a group of peers in a small-seminar setting. These seminars are offered in all campus departments; topics vary from department to department and from semester to semester. Enrollment limits are set by the faculty, but the suggested limit is 25. (F,SP)

39K. Freshman/Sophomore Seminar. (2-4) Course may be repeated for credit as topic varies. Two to four hours of seminar per week. Sections 1-2 to be graded on a letter-grade basis. Sections 3-4 to be graded on a *passed/not passed* basis. *Prerequisites: Priority given to freshmen and sophomores.* Freshman and sophomore seminars offer lower division students the opportunity to explore an intellectual topic with a faculty member and a group of peers in a small-seminar setting. These seminars are offered in all campus departments; topics vary from department to department and from semester to semester. Enrollment limits are set by the faculty, but the suggested limit is 25. (F,SP)

39L. Freshman/Sophomore Seminar. (2-4) Course may be repeated for credit as topic varies. Two to four hours of seminar per week. Sections 1-2 to be graded on a letter-grade basis. Sections 3-4 to be graded on a *passed/not passed* basis. *Prerequisites: Priority given to freshmen and sophomores.* Freshman and sophomore seminars offer lower division students the opportunity to explore an intellectual topic with a faculty member and a group of peers in a small-seminar setting. These seminars are offered in all campus departments; topics vary from department to department and from semester to semester. Enrollment limits are set by the faculty, but the suggested limit is 25. (F,SP)

47A. Completion of Work in Computer Science 61A. (1) Students will receive no credit for 47A after taking 61A. Self-paced. *Prerequisites: 61B or equivalent, 9D, and consent of instructor.* Implementation of generic operations. Streams and iterators. Implementation techniques for supporting functional, object-oriented, and constraint-based programming in the Scheme programming language. Together with 9D, 47A constitutes an abbreviated, self-paced version of 61A for students who have already taken a course equivalent to 61B. (F,SP) *Clancy, Garcia*

47B. Completion of Work in Computer Science 61B. (1) Students will receive no credit for 47B after taking 61B. Self-paced. *Prerequisites: A course in data structures, 9G or equivalent, and consent of instructor.* Iterators. Hashing, applied to strings and multi-dimensional structures. Heaps. Storage management. Design and implementation of a program containing hundreds of lines of code. Students with sufficient partial credit in 61B may, with consent of instructor, complete the credit in this self-paced course. (F,SP) *Clancy, Garcia*

47C. Completion of Work in Computer Science 61C. (1) Students will receive no credit for 47C after taking 61C. Self-paced. *Prerequisites: Experience with assembly language including writing an interrupt handler, 9C or equivalent, and consent of instructor.* MIPS instruction set simulation. The assembly and linking process. Caches and virtual memory. Pipelined computer organization.

Students with sufficient partial credit in 61C may, with consent of instructor, complete the credit in this self-paced course. (F,SP) *Clancy, Garcia*

61A. The Structure and Interpretation of Computer Programs. (4) Students will receive no credit for 61A after taking 47A. Three hours of lecture, one and one-half hours of discussion, and one and one-half hours of laboratory and two and one-half hours of unscheduled laboratory per week. *Prerequisites: Mathematics 1A (may be taken concurrently); programming experience equivalent to that gained in 3 or the Advanced Placement Computer Science A course.* Introduction to programming and computer science. This course exposes students to techniques of abstraction at several levels: (a) within a programming language, using higher-order functions, manifest types, data-directed programming, and message-passing; (b) between programming languages, using functional and rule-based languages as examples. It also relates these techniques to the practical problems of implementation of languages and algorithms on a von Neumann machine. There are several significant programming projects, programmed in a dialect of the LISP language. (F,SP) *Clancy, Garcia, Harvey*

61B. Data Structures. (4) Students will receive no credit for 61B after taking 61BL. Three hours of lecture, one hour of discussion, two hours of programming laboratory, and an average of six hours of self-scheduled programming laboratory per week. *Prerequisites: 61A with a grade of B- or better.* Fundamental dynamic data structures, including linear lists, queues, trees, and other linked structures; arrays strings, and hash tables. Storage management. Elementary principles of software engineering. Abstract data types. Algorithms for sorting and searching. Introduction to the Java programming language. (F,SP) *Clancy, Hilfinger, Shewchuk*

61BL. Data Structures and Programming Methodology. (4) Students will receive no credit for 61BL after taking 61B. One hour of lecture and six hours of laboratory per week and an average of five hours of self-scheduled programming laboratory. *Prerequisites: A grade of B- or better in 61A.* The same material as in 61B, but in a laboratory-based format. (F,SP) *Clancy, Hilfinger*

61C. Machine Structures. (4) Students will receive no credit for 61C after taking 47C. Three hours of lecture, two hours of laboratory, and one hour of discussion per week. *Prerequisites: 61B or 47B.*The internal organization and operation of digital computers. Machine architecture, support for high-level languages (logic, arithmetic, instruction sequencing) and operating systems (I/O, interrupts, memory management, process switching). Elements of computer logic design. Tradeoffs involved in fundamental architectural design decisions. (F,SP) *Clancy, Wawrzynek, Staff*

61CL. Machine Structures. (4) Students will receive no credit for 61CL after taking 61C. One hour of lecture and six hours of laboratory per week. *Prerequisites: 61B or 61BL.* The same material as in 61C but in a laboratory-based format. (F,SP) *Clancy, Peterson*

70. Discrete Mathematics and Probability Theory. (4) Students will receive no credit for 70 after taking Mathematics 55. Three hours of lecture per week, or three hours of lecture and two hours of discussion per week. *Prerequisites: Sophomore mathematical maturity, and programming experience equivalent to that gained in 3 or the Advanced Placement Computer Science A course.* Logic, infinity, and induction; applications include undecidability and stable marriage problem. Modular arithmetic and GCDs; applications include primality testing and cryptography. Polynomials; examples include error correcting codes and interpolation. Probability including sample spaces, independence, random variables, law of large numbers; examples include load balancing, existence arguments, Bayesian inference. *Demmel, Papadimitriou, Sinclair, Vazirani*

84. Sophomore Seminar. (1,2) Course may be repeated for credit as topic varies. One hour of seminar per week per unit for fifteen weeks. One and one half hours of seminar per week per unit for 10 weeks. Two hours of seminar per week per unit for eight weeks. Three hours of seminar per week per unit for five weeks. Sections 1-2 to be graded on a *passed/not passed* basis. Sections 3-4 to be graded on a letter-grade basis. *Prerequisites: At discretion of instructor.* Sophomore seminars are small interactive courses offered by faculty members in departments all across the campus. Sophomore seminars offer opportunity for close, regular intellectual contact between faculty members and students in the crucial second year. The topics vary from department to department and semester to semester. Enrollment limited to 15 sophomores. (F,SP)

98. Directed Group Study. (1-4) Course may be repeated for credit. One hour of lecture per week per unit. Must be taken on a *passed/not passed* basis. *Prerequisites: Consent of instructor.* Seminars for group study of selected topics, which will vary from year to year. Intended for students in the lower division. (F,SP) *Staff*

99. Individual Study and Research for Undergraduates. (1-2) Course may be repeated for credit. Must be taken on a *passed/not passed* basis. *Prerequisites: GPA of 3.4 or better.* A course for lower division students in good standing who wish to undertake a program of individual inquiry initiated jointly by the student and a professor. There are no other formal prerequisites, but the supervising professor must be convinced that the student is able to profit by the program. (F,SP) *Staff*

Computer Science Upper Division Courses

150. Components and Design Techniques for Digital Systems. (5) Three hours of lecture, one hour of discussion, and three hours of laboratory per week. *Prerequisites: 61C, Electrical Engineering 40 or 42.* Basic building blocks and design methods to construct synchronous digital systems. Alternative representations for digital systems. Bipolar TTL vs. MOS implementation technologies. Standard logic (SSI, MSI) vs. programmable logic (PLD, PGA). Finite state machine design. Digital computer building blocks as case studies. Introduction to computer-aided design software. Formal hardware laboratories and substantial design project. Informal software laboratory periodically throughout semester. (F,SP) *Katz, Pister, Wawrzynek*

152. Computer Architecture and Engineering. (5) Three hours of lecture and two hours of discussion per week. *Prerequisites: 61C.* Instruction set design, Register Transfer. Computer design project requiring about 100 hours. Data-path design. Controller design. Memory system. Addressing. Microprogramming. Computer arithmetic. Survey of real computers and microprocessors. (F,SP) *Culler, Kubiatowicz, Wawrzynek*

160. User Interface Design and Development. (4) Three hours of lecture, 1 hour of discussion, and four hours of self-scheduled programming laboratory per week. *Prerequisites: 61B.* The design, implementation, and evaluation of human/computer interfaces. Interface devices (keyboard, pointing, display, audio, etc.), metaphors (desktop, notecards, rooms, ledger sheets, tables, etc.), interaction styles and dialog models, design examples, and user-centered design and task analysis. Interface-development methodologies, implementation tools, testing, and quality assessment. Students will develop a direct-manipulation interface. *Agrawala, Bajcsy, Canny*

161. Computer Security. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 61C (Machine Structures), plus either 70 (Discrete Mathematics) or Mathematics 55.*Introduction to computer security. Cryptography, including encryption, authentication, hash functions, cryptographic protocols, and applications. Operating system security, access control. Network security, firewalls, viruses, and worms. Software security, defensive programming, and language-based security. Case studies from real-world systems. (F,SP) *Joseph, Tygar, Vazirani, Wagner*

162. Operating Systems and System Programming. (4) Three hours of lecture, one hour of discussion, and four hours of programming laboratory per week. *Prerequisites: 61B, 61C, and Math 55.* Basic concepts of operating systems and system programming. Utility programs, subsystems, multiple-program systems. Processes, interprocess communication, and synchronization. Memory allocation, segmentation, paging. Loading and linking, libraries. Resource allocation, scheduling, performance evaluation. File systems, storage devices, I/O systems. Protection, security, and privacy. (F,SP) *Joseph, Kubiatowicz, Smith*

164. Programming Languages and Compilers. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 61B and 61C.* Survey of programming languages. The design of modern programming languages. Principles and techniques of scanning, parsing, semantic analysis, and code generation. Implementation of compilers, interpreters, and assemblers. Overview of run-time organization and error handling. (F,SP) *Bodik, Hilfinger, Necula*

169. Software Engineering. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 61B and 61C, Math 55 or 113.* Ideas and techniques for designing, developing, and modifying large software systems. Function-oriented and object-oriented modular design techniques, designing for re-use and maintainability. Specification and documentation. Verification and validation. Cost and quality metrics and estimation. Project team organization and management. Students will work in teams on a substantial programming project. (F,SP) *Bodik, Brewer, Keutzer, Necula, Sen*

170. Efficient Algorithms and Intractable Problems. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 61B, Mathematics 55.* Concept and basic techniques in the design and analysis of algorithms; models of computation; lower bounds; algorithms for optimum search trees, balanced trees and UNION-FIND algorithms; numerical and algebraic algorithms; combinatorial algorithms. Turing machines, how to count steps, deterministic and nondeterministic Turing machines, NP-completeness. Unsolvable and intractable problems. (F,SP) *Sinclair, Papadimitriou, Rao, Vazirani*

172. Computability and Complexity. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 170.* Finite automata, Turing machines and RAMs. Undecidable, exponential, and polynomial-time problems. Polynomial-time equivalence of all reasonable models of computation. Nondeterministic Turing machines. Theory of NP-completeness: Cook's theorem, NP-completeness of basic problems. Selected topics in language theory, complexity and randomness. (F,SP) *Papadimitriou, Sestia, Sinclair, Vazirani*

174. Combinatorics and Discrete Probability. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 170.* Permutations, combinations, principle of inclusion and exclusion, generating functions, Ramsey theory. Expectation and variance, Chebychev's inequality, Chernov bounds. Birthday paradox, coupon collector's problem, Markov chains and entropy computations, universal hashing, random number generation, random graphs and probabilistic existence bounds. (F,SP) *Canny, Papadimitriou, Sinclair, Vazirani*

C182. The Neural Basis of Thought and Language. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 61B; Cognitive Science C101, Linguistics C105 or Cognitive Science C100, Psychology C120B; or consent of instructor.* This is a course on the current status of interdisciplinary studies that seeks to answer the following questions: (1) How is it possible for the human brain, which is a highly structured network of neurons, to think and to learn, use, and understand language? (2) How are language and thought related to perception, motor control, and our other neural systems, including social cognition? (3) How do the computational properties of neural systems and the specific neural structures of the human brain shape the nature of thought and language? Much of the course will focus on the Neural Theory of Language (NTL), which seeks to answer these questions in terms of architecture and mechanism, using models and simulations of language and learning phenomena. Also listed as Cognitive Science C110 and Linguistics C109. (SP)

184. Foundations of Computer Graphics. (4) Three hours of lecture, one hour of discussion, and three hours of laboratory per week. *Prerequisites: 61B; programming skills in C, C++, or Java; linear algebra and calculus.* Techniques of modeling objects for the purpose of computer rendering: boundary representations, constructive solids geometry, hierarchical scene descriptions. Mathematical techniques for curve and surface representation. Basic elements of a computer graphics rendering pipeline; architecture of modern graphics display devices. Geometrical transformations such as rotation, scaling, translation, and their matrix representations. Homogeneous coordinates, projective and perspective transformations. Algorithms for clipping, hidden surface removal, rasterization, and anti-aliasing. Scan-line based and ray-based rendering algorithms. Lighting models for reflection, refraction, transparency. (F,SP) *Barsky, O'Brien, Sequin*

186. Introduction to Database Systems. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 61B and 61C.* Access methods and file systems to facilitate data access. Hierarchical, network, relational, and object-oriented data models. Query languages for models. Embedding query languages in programming languages. Database services including protection, integrity control, and alternative views of data. High-level interfaces including application generators, browsers, and report writers. Introduction to transaction processing. Database system implementation to be done as term project. (F,SP) *Franklin, Hellerstein*

188. Introduction to Artificial Intelligence. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 61A or 61B and consent of instructor; 70 or Mathematics 55.* Basic ideas and techniques underlying the design of intelligent computer systems. Topics include heuristic search, problem solving, game playing, knowledge representation, logical inference, planning, reasoning under uncertainty, expert systems, learning, perception, language understanding. (F,SP) *Klein, Malik*

C191. Quantum Information Science and Technology. (3) Three hours of lecture/discussion per week. *Prerequisites: Mathematics 54, Physics 7A-7B, and either Physics 7C, Mathematics 55, or Computer Science 170.* This multidisciplinary course provides an introduction to fundamental conceptual aspects of quantum mechanics from a computational and informational theoretic perspective, as well as physical implementations and technological applications of quantum information science. Basic sections of quantum algorithms, complexity, and cryptography, will be touched upon, as well as pertinent physical realizations from nanoscale science and engineering. Also listed as Physics C191 and Chemistry C191. (F,SP) *Crommie, Vazirani, Whaley*

194. Special Topics. (1-4) Course may be repeated for credit as topic varies. One to fours hours of lecture/discussion per week. *Prerequisites: Consent of instructor.* Topics will vary semester to semester. See the Computer Science Division announcements. (F,SP) *Staff*

195. Social Implications of Computer Technology. (2) Three hours of lecture/discussion per week. Must be taken on a *passed/not passed* basis. *Prerequisites: Major in EECS or CS or consent of instructor.* Topics include electronic community; the changing nature of work; technological risks; the information economy; intellectual property; privacy; artificial intelligence and the sense of self; pornography and censorship; professional ethics. Students will lead discussions on some of these topics. (SP) *Harvey*

C195. Social Implications of Computer Technology. (2) Three hours of lecture/discussion per week. Must be taken on a *passed/not passed* basis. Topics include electronic community; the changing nature of work; technological risks; the information economy; intellectual property; privacy; artificial intelligence and the sense of self; pornography and censorship; professional ethics. Students will lead discussions on some of these topics. Also listed as Interdisciplinary Studies Field Maj C155. *Harvey*

H196A-H196B. Senior Honors Thesis Research. (1-4;1-4) Individual research. *Prerequisites: Open only to students in the computer science honors program.* Thesis work under the supervision of a faculty member. To obtain credit the student must, at the end of two semesters, submit a satisfactory thesis to the Electrical Engineering and Computer Science department archive. A total of four units must be taken. The units many be distributed between one or two semesters in any way. H196A-H196B count as graded technical elective units, but may not be used to satisfy the requirement for 27 upper division technical units in the College of Letters and Science with a major in Computer Science. (F,SP)

198. Directed Group Studies for Advanced Undergraduates. (1-4) Course may be repeated for credit. Course format varies with section. Must be taken on a *passed/not passed* basis. *Prerequisites: 2.0 GPA or better; 60 units completed.* Group study of selected topics in Computer Sciences, usually relating to new developments.

199. Supervised Independent Study. (1-4) Enrollment is restricted; see the Introduction to Courses and Curricula section of this catalog. Individual conferences. Must be taken on a *passed/not passed* basis. *Prerequisites: Consent of instructor and major adviser.* Supervised independent study. Enrollment restrictions apply. (F,SP) *Staff*

Computer Science Graduate Courses

250. VLSI Systems Design. (4) Three hours of lecture and four hours design laboratory per week. *Prerequisites: 150.* Unified top-down and bottom-up design of integrated circuits and systems concentrating on architectural and topological issues. VLSI architectures, systolic arrays, self-timed systems. Trends in VLSI development. Physical limits. Tradeoffs in custom-design, standard cells, gate arrays. VLSI design tools. (F) *Wawrzynek*

252. Graduate Computer Architecture. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 152.* Graduate survey of contemporary computer organizations covering: early systems, CPU design, instruction sets, control, processors, busses, ALU, memory, I/O interfaces, connection networks, virtual memory, pipelined computers, multiprocessors, and case studies. Term paper or project is required. (F,SP) *Culler, Kubiatowicz, Patterson*

258. Parallel Processors. (3) Three hours of lecture per week. *Prerequisites: 252.* In-depth study of the design, engineering, and evaluation of modern parallel computers. Fundamental design: naming, synchronization, latency, and bandwidth. Architectural evolution and technological driving forces. Parallel programming models, communication primitives, programming and compilation techniques, multiprogramming workloads and methodology for quantitative evaluation. Latency avoidance through replication in small-scale and large-scale shared memory designs; cache-coherency, protocols, directories, and memory consistency models. Message passing: protocols, storage management, and deadlock. Efficient network interface, protection, events, active messages, and coprocessors in large-scale designs. Latency tolerance through prefetching, multithreading, dynamic instruction scheduling, and software techniques. Network design: topology, packaging, k-ary n-cubes, performance under contention. Synchronization: global operations, mutual exclusion, and events. Alternative architectures: dataflow, SIMD, systoltic arrays. *Culler*

260. User-Interfaces to Computer Systems. (3) Three hours of lecture per week. *Prerequisites: 162 and 164 recommended, or consent of instructor. Formerly CS 287*. Design and implementation of user-interfaces to computer systems. Software and hardware architectures for personal workstations. Object-oriented programming systems. Form-based user-interfaces. Window and display management abstractions. Case studies of naive- and expert-user interfaces. Students will complete a substantial project. *Canny*

261. Security in Computer Systems. (3) Three hours of lecture per week. *Prerequisites: 162.*Graduate survey of modern topics in computer security, including protection, access control, distributed access security, firewalls, secure coding practices, safe languages, mobile code, and case studies from real-world systems. May also cover cryptographic protocols, privacy and anonymity, and/or other topics as time permits. (SP) *Brewer*

262A. Advanced Topics in Computer Systems. (4) Three hours of lecture per week. *Prerequisites: 162 and entrance exam. Formerly 262.* Graduate survey of systems for managing computation and information, covering a breadth of topics: early systems; volatile memory management, including virtual memory and buffer management; persistent memory systems, including both file systems and transactional storage managers; storage metadata, physical vs. logical naming, schemas, process scheduling, threading and concurrency control; system support for networking, including remote procedure calls, transactional RPC, TCP, and active messages; security infrastructure; extensible systems and APIs; performance analysis and engineering of large software systems. Homework assignments, exam, and term paper or project required. (F,SP) *Hellerstein*

262B. Advanced Topics in Computer Systems. (3) Three hours of lecture per week. *Prerequisites: 262A.* Continued graduate survey of large-scale systems for managing information and computation. Topics include basic performance measurement; extensibility, with attention to protection, security, and management of abstract data types; index structures, including support for concurrency and recovery; parallelism, including parallel architectures, query processing and scheduling; distributed data management, including distributed and mobile file systems and databases; distributed caching; large-scale data analysis and search. Homework assignments, exam, and term paper or project required. (F,SP) *Brewer, Franklin, Hellerstein, Joseph*

263. Design of Programming Languages. (3) Three hours of lecture and one hour of discussion per week. *Prerequisites: 164.* Selected topics from: analysis, comparison, and design of programming languages, formal description of syntax and semantics, advanced programming techniques, structured programming, debugging, verification of programs and compilers, and proofs of correctness. *Yelick*

264. Implementation of Programming Languages. (4) Three hours of lecture, one hour of discussion, and six hours programming laboratory per week. *Prerequisites: 164, 263 recommended.* Compiler construction. Lexical analysis, syntax analysis. Semantic analysis code generation and optimization. Storage management. Run-time organization. *Graham*

265. Compiler Optimization and Code Generation. (3) Three hours of lecture per week. *Prerequisites: 164.*Table-driven and retargetable code generators. Register management. Flow analysis and global optimization methods. Code optimization for advanced languages and architectures. Local code improvement. Optimization by program transformation. Selected additional topics. A term paper or project is required. *Graham*

266. Introduction to System Performance Analysis. (3) Three hours of lecture per week. *Prerequisites: 162 and Statistics 5. Formerly 267 and 268.*Performance indices. Evaluation techniques. Measurement: instrumentation, design of experiments, interpretation of results. Simulation modeling: simulator design, model calibration, statistical analysis of output data. Introduction to analytic modeling. Workload characterization. Tuning, procurement, and capacity planning application. Program performance evaluation. File and I/O system optimization. CPU Scheduling and architecture performance analysis. *Smith*

C267. Applications of Parallel Computers. (3) Three hours of lecture and one hour of laboratory per week. Models for parallel programming. Fundamental algorithms for linear algebra, sorting, FFT, etc. Survey of parallel machines and machine structures. Exiting parallel programming languages, vectorizing compilers, environments, libraries and toolboxes. Data partitioning techniques. Techniques for synchronization and load balancing. Detailed study and algorithm/program development of medium sized applications. Also listed as Engineering C233. *Demmel, Yelick*

268. Computer Networks. (3) 292V Three hours of lecture per week. *Prerequisites: 162.*Distributed systems, their notivations, applications, and organization. The network component. Network architectures. Local and long-haul networks, technologies, and topologies. Data link, network, and transport protocols. Point-to-point and broadcast networks. Routing and congestion control. Higher-level protocols. Naming. Internetworking. Examples and case studies. *Joseph, Katz, Stoica*

270. Combinatorial Algorithms and Data Structures. (3) Three hours of lecture and one hour of discussion per week. *Prerequisites: 170.*Design and analysis of efficient algorithms for combinatorial problems. Network flow theory, matching theory, matroid theory; augmenting-path algorithms; branch-and-bound algorithms; data structure techniques for efficient implementation of combinatorial algorithms; analysis of data structures; applications of data structure techniques to sorting, searching, and geometric problems. *Papadimitriou, Sinclair, Vazirani*

271. Randomness and Computation. (3) Three hours of lecture per week. *Prerequisites: 170 and at least one course numbered 270-279.*Computational applications of randomness and computational theories of randomness. Approximate counting and uniform generation of combinatorial objects, rapid convergence of random walks on expander graphs, explicit construction of expander graphs, randomized reductions, Kolmogorov complexity, pseudo-random number generation, semi-random sources. *Sinclair*

273. Foundations of Parallel Computation. (3) Three hours of lecture per week. *Prerequisites: 170, or consent of instructor. Formerly 292K*. Fundamental theoretical issues in designing parallel algorithms and architectures. Shared memory models of parallel computation. Parallel algorithms for linear algebra, sorting, Fourier Transform, recurrence evaluation, and graph problems. Interconnection network based models. Algorithm design techniques for networks like hypercubes, shuffle-exchanges, threes, meshes and butterfly networks. Systolic arrays and techniques for generating them. Message routing. *Staff*

274. Computational Geometry. (3) Course may be repeated for credit. Three hours of lecture per week. *Prerequisites: 170 or equivalent. Formerly 292T.* Constructive problems in computational geometry: convex hulls, triangulations, Voronoi diagrams, arrangements of hyperplanes; relationships among these problems. Search problems: advanced data structures; subdivision search; various kinds of range searches. Models of computation; lower bounds. *Staff*

276. Cryptography. (3) Three hours of lecture per week. *Prerequisites: 170.*Graduate survey of modern topics on theory, foundations, and applications of modern cryptography. One-way functions; pseudorandomness; encryption; authentication; public-key cryptosystems; notions of security. May also cover zero-knowledge proofs, multi-party cryptographic protocols, practical applications, and/or other topics, as time permits. (F,SP) *Trevisan, Wagner*

278. Machine-Based Complexity Theory. (3) Three hours of lecture per week. *Prerequisites: 170.* Properties of abstract complexity measures; Determinism vs. nondeterminism; time vs. space; complexity hierarchies; aspects of the P-NP question; relative power of various abstract machines. *Vazirani*

C280. Computer Vision. (3) Three hours of lecture per week. *Prerequisites: Knowledge of linear algebra and calculus. Mathematics 1A-1B, 53, 54 or equivalent.* Paradigms for computational vision. Relation to human visual perception. Mathematical techniques for representing and reasoning, with curves, surfaces and volumes. Illumination and reflectance models. Color perception.

Image segmentation and aggregation. Methods for bottom-up three dimensional shape recovery: Line drawing analysis, stereo, shading, motion, texture. Use of object models for prediction and recognition. Also listed as Vision Science C280. *Malik, Forsyth*

C281A. Statistical Learning Theory. (3) Three hours of lecture per week. *Prerequisites: Linear algebra, calculus, basic probability, and statistics, algorithms. Recommended 289.*Classification regression, clustering, dimensionality, reduction, and density estimation. Mixture models, hierarchical models, factorial models, hidden Markov, and state space models, Markov properties, and recursive algorithms for general probabilistic inference nonparametric methods including decision trees, kernel methods, neural networks, and wavelets. Ensemble methods. Also listed as Statistics C241A. (F)

C281B. Advanced Topics in Learning and Decision Making. (3) Three hours of lecture per week. *Prerequisites: C281A, Statistics C241A.* Recent topics include: Graphical models and approximate inference algorithms. Markov chain Monte Carlo, mean field and probability propagation methods. Model selection and stochastic realization. Bayesian information theoretic and structural risk minimization approaches. Markov decision processes and partially observable Markov decision processes. Reinforcement learning. Also listed as Statistics C241B. (SP)

282. Algebraic Algorithms. (3) Three hours of lecture per week. *Prerequisites: 164, Mathematics 113B, or permission of instructor.* Theory and construction of symbolic algebraic computer programs. Polynomial arithmetic, GCD, factorization, integration of elementary functions, analytic approximation, simplification, design of computer systems and languages for symbolic manipulation. *Fateman*

284. Computer-Aided Geometric Design and Modeling. (3) Three hours of lecture per week. *Prerequisites: Mathematical skill in calculus and linear algebra.* Mathematical techniques for curve and surface representation, including: Hermite interpolation, interpolatory splines, tensed splines, Bezier curves and surfaces, B-splines, Beta-splines, Coons patches, tensor product forms, as well as subdivision end/bounding conditions, and computational considerations. *Barsky*

285. Solid Free-Form Modeling and Fabrication. (3) Three hours of lecture per week. *Prerequisites: 184.*From shape design to computer-based descriptions suitable for manufacturing or rapid prototyping. Solid modeling techniques and procedural shape generation. Effective data structures and unambiguous part description formats. Algorithms for dealing with Boolean operations and for machine tool path planning. Problems of finite-precision geometry and machining tolerances. Introduction to some rapid prototyping techniques based on Solid Free-Form Fabrication and NC machining. Other advanced topics and recent developments in the field. *Sequin*

286. Implementation of Data Base Systems. (3) Three hours of lecture per week. *Prerequisites: 162 and 186.*Implementation of data base systems on modern hardware systems. Considerations concerning operating system design, including buffering, page size, prefetching, etc. Query processing algorithms, design of crash recovery and concurrency control systems. Implementation of distributed data bases and data base machines. *Hellerstein*

287. Advanced Robotics. (3) Three hours of lecture per week. *Prerequisites: Electrical Engineering 125.*Advanced topics related to current research in robotics. Planning and control issues for realistic robot systems, taking into account: dynamic constraints, control and sensing uncertainty, and non-holonomic motion constraints. Analysis of friction for assembly and grasping tasks. Sensing systems for hands including tactile and force sensing. Environmental perception from sparse sensors for dexterous hands. Grasp planning and manipulation. *Canny*

288. Artificial Intelligence Approach to Natural Language Processing. (3) Three hours of lecture per week plus programming assignment. *Prerequisites: 164.*Representation of conceptual structures, language analysis and production, models of inference and memory, high-level text structures, question answering and conversation, machine translation. *Klein, Malik*

289. Knowledge Representation and Use in Computers. (3) Three hours of lecture per week. *Prerequisites: 188 or equivalent.* Fundamentals of knowledge representation and use in computers. Predicate calculus, non-monotonic logics, probability and decision theory, and their use in capturing commonsense and expert knowledge. Theorem-provers, planning systems belief networks and influence diagrams as reasoning methods. Integrated architectures for intelligent agents. A project will be undertaken. *Russell*

C293A. Vision A: Quantitative, Perceptual, and Physiological Aspects. (2) Three hours of lecture per week for seven and one-half weeks. *Prerequisites: Consent of instructor.* The course will present basic material on the retina and visual pathways, psychophysical measurements, visual sensitivity, color vision, and the estimation of disparity and motion. Introduction to front-end visual processing in mammalian visual system. Basic optics, anatomy and physiology of retina, lateral geniculate nucleus, and primary visual cortex. Psychophysics of color, light and dark adaptation, spatial contrast sensitivity, spatial resolution, spatiotemporal contrast sensitivity, motion and disparity measurement. Connections between psychophysics and physiology. Relevant modeling techniques such as linear systems, signal detection theory, and information theory will be introduced and applied. There will be an accompanying laboratory which the students can register for separately. Also listed as Psychology C215A, Vision Science C290A, and Molecular and Cell Biology C264A.

C293B. Vision B: Quantitative, Perceptual, and Physiological Aspects. (2) Three hours of lecture per week for seven and one-half weeks. *Prerequisites: Consent of instructor.* The course will present basic material on inferring 3d from visual information. This will include disparity, motion, texture, shading, and occlusion. Introduction to the psychophysics and mathematical analysis underlying the inference of 3d scene properties from 2d retinal images. Psychophysics of various cues to 3d shape and spatial layout such as texture, contour, shading, stereopsis, and structure from motion. Geometrical analysis of these cues. Probabilitic theory for optimal combination of cues and estimation of scene properties. Relevant physiology of V1, V2, V4, and higher areas. Also listed as Psychology C215B, Vision Science C290B, and Molecular and Cell Biology C264B.

C293C. Vision C: Perceptual Organization. (2) Three hours of lecture per week for seven and one-half weeks. *Prerequisites: Consent of instructor.* This course will cover "mid-level" visual processing, including the perception of objects, their properties, and the determination of part-whole structure from optical images. The approach will be interdisciplinary, including material from psychophysics, classical perceptual psychology, computational modeling, and neuroscience. Specific topics include perception of color, grouping, figure-ground organization, modal and amodal completion, and part-whole structure. Also listed as Molecular and Cell Biology C264C, Vision Science C290C, and Psychology C215C.

C293D. Vision D: High-Level Vision. (2) Three hours of lecture per week for seven and one-half weeks. *Prerequisites: Consent of instructor.* This course will cover "high-level" visual processing, including object recognition, visual attention, visual memory, visual imagery, and visual awareness. The approach will be interdisciplinary, including material from psychophysics, classical perceptual psychology, computational modeling and neurosciences. Also listed as Molecular and Cell Biology C264D, Vision Science C290D, and Psychology C215D.

C293L. Vision Laboratory: Quantitative, Perceptual, and Physiological Aspects. (1) Course may be repeated for credit. One hour of laboratory per week for seven and one-half weeks. *Prerequisites: Consent of instructor.* Quantitative analysis of psychophysical properties of spatial, color, temporal and binocular vision, motion sensitivity and adaptation and their underlying physiological mechanisms. Also listed as Psychology C215L, Vision Science C290L, and Molecular and Cell Biology C264L.

294. Special Topics. (1-4) Course may be repeated for credit. Topics will vary from semester to semester. See Computer Science Division announcements. (F,SP) *Staff*

297. Field Studies in Computer Science. (1-12) Course may be repeated for credit. Independent study. Must be taken on a *satisfactory/unsatisfactory* basis. Supervised experience in off-campus companies relevant to specific aspects and applications of electrical engineering and/or computer science. Written report required at the end of the semester. (F,SP)

298. Group Studies Seminars, or Group Research. (1-4) Course may be repeated for credit. One to four hours per unit. Sections 1-25 to be graded on a *satisfactory/unsatisfactory* basis. Sections 26-35 to be graded on a letter-grade basis. Advanced study in various subjects through seminars on topics to be selected each year, informal group studies of special problems, group participation in comprehensive design problems, or group research on complete problems for analysis and experimentation. (F,SP) *Staff*

299. Individual Research. (1-12) Course may be repeated for credit. Investigations of problems in computer science. (F,SP) *Staff*

602. Individual Study for Doctoral Students. (1-8) Course may be repeated for credit. Course does not satisfy unit or residence requirements for doctoral degree. Independent study, consultation with faculty member. Must be taken on a *satisfactory/unsatisfactory* basis. Individual study in consultation with the major field adviser, intended to provide an opportunity for qualified students to prepare themselves for the various examinations required of candidates for the Ph.D. (and other doctoral degrees). (F,SP) *Staff*

Professional Courses

300. Teaching Practice. (1-6) Course may be repeated for credit. Three to twenty hours of discussion and consulting per week. Must be taken on a *satisfactory/unsatisfactory* basis. Supervised teaching practice, in either a one-on-one tutorial or classroom discussion setting. (F,SP) *Staff*

301. Teaching Techniques for Computer Science. (1) Course may be repeated for credit. One hour of discussion per week. Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisites: Consent of instructor.* Discussion and practice of techniques for effective teaching. (F,SP) *Clancy, Garcia, Harvey*

302. Designing Computer Science Education. (3) Two hours of lecture per week. *Prerequisites: Computer Science 301 and two semesters of GSI experience.* Discussion and review of research and practice relating to the teaching of computer science: knowledge organization and misconceptions, curriculum and topic organization, evaluation, collaborative learning, technology use, and administrative issues. As part of a semester-long project to design a computer science course, participants invent and refine a variety of homework and exam activities, and evaluate alternatives for textbooks, grading and other administrative policies, and innovative uses of technology. (SP) *Clancy*

399. Professional Preparation: Supervised Teaching of Computer Science. (1,2) Course may be repeated for credit. One hour of meeting with instructor plus 10 hours (1 unit) or 20 hours (2 units) of teaching per week. Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisites: Appointment as graduate student instructor.* Discussion, problem review and development, guidance of computer science laboratory sections, course development, supervised practice teaching. (F,SP) *Staff*

Most of these courses offer concentrated coverage of their subject area, generally requiring substantial time for problem sets. It is not unusual for a student in electromagnetic theory, quantum, optics and cryo-electronics, solid-state, or plasmas to take roughly half of their graduate courses in physics.

6.1.3 Physics

(As a supplement to EECS Course Offerings)

Upper Division Courses

Some courses in physics, EECS and other branches of engineering share similar names and catalog descriptions but have considerable differences in content and empasis. Many courses in physics are appropriate for EECS graduate students. Broadly speaking, courses in physics tend to emphasize theory, while those in engineering concentrate more on application.

105. Analytic Mechanics. (4) Three hours of lecture and one hour of discussion per week. Newtonian mechanics, motion of a particle in one, two, and three dimensions, Larange's equations, Hamilton's equations, central force motion, moving coordinate systems, mechanics of continuous media, oscillations, normal modes, rigid body dynamics, tensor analysis techniques. (F,SP) *Staff*

110A-110B. Electromagnetism and Optics. (4;4) Three hours of lecture and one hour of discussion per week. A course emphasizing electromagnetic theory and applications; charges and currents; electric and magnetic fields; dielectric, conducting, and magnetic media; relativity, Maxwell equations. Wave propagation in media, radiation and scattering, Fourier optics, interference and diffraction, ray optics and applications. (F,SP) *Staff*

112. Introduction to Statistical and Thermal Physics. (4) Three hours of lecture and one hour of discussion per week. Basic concepts of statistical mechanics, microscopic basis of thermodynamics and applications to macroscopic systems, condensed states, phase transformations, quantum distributions, elementary kinetic theory of transport processes, fluctuation phenomena. (F,SP) *Staff*

137A-137B. Quantum Mechanics. (4;4) Three hours of lecture and one hour of discussion per week. Introduction to the methods of quantum mechanics with applications to atomic, molecular, solid state, nuclear and elementary particle physics. (F,SP) *Staff*

141A-141B. Solid State Physics. (4;3) Three hours of lecture and one hour of discussion per week. *Prerequisites: 137A-137B; 137B may be taken concurrently.* A thorough introductory course in modern solid state physics. Crystal symmetries; classification of solids and their bonding; electromagnetic, elastic, and particle waves in periodic lattices; thermal magnetic and dielectric properties of solids; energy bands of metals and semi-conductors; superconductivity; magnetism; ferroelectricity; magnetic resonances. (F,SP) *Staff*

142. Introduction to Plasma Physics. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 105, 110A-110B (110B may be taken concurrently).* Motion of charged particles in electric and magnetic fields, dynamics of fully ionized plasma from both microscopic and macroscopic point of view, magnetohydrodynamics, small amplitude waves; examples from astrophysics, space sciences and controlled-fusion research. (SP) *Staff*

Graduate Courses

205A. Advanced Dynamics. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 105 or equivalent.* Lagrange and Hamiltonian dynamics, variational methods, symmetry, kinematics and dynamics of rotation, canonical variables and transformations, perturbation theory, non-linear dynamics, KAM theory. (F) *Staff*

205B. Advanced Dynamics. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 205A.* Continuous systems, dissipative systems. Attractors. Emphasis on recent developments, including turbulence. (SP) *Staff*

211. Equilibrium Statistical Physics. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 112 or equivalent.* Foundations of statistical physics. Ensemble theory. Degenerate systems. Systems of interacting particles. (F) *Staff*

212. Nonequilibrium Statistical Physics. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 112 and 221A-221B, or equivalents.* Time dependent processes. Kinetic equations. Transport processes. Irreversibility. Theory of many-particle systems. Fluctuation phenomena. (SP) *Staff*

221A. Quantum Mechanics. (5) Three hours of lecture and one hour of discussion per week. *Prerequisites: 137A-137B or equivalent.* Basic assumptions of quantum mechanics; quantum theory of measurement; matrix mechanics; Schroedinger theory; symmetry and invariance principles; theory of angular momentum; stationary state problems; variational principles; time independent perturbation theory; time dependent perturbation theory; theory of scattering. (F) *Staff*

221B. Quantum Mechanics. (5) Three hours of lecture and one hour of discussion per week. *Prerequisites: 221A.* Many-body methods, radiation field quantization, relativistic quantum mechanics, applications. (SP) *Staff*

240A-240B. Quantum Theory of Solids. (4;4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 141A-141B and 221A-221B or equivalents, or consent of instructor; 240A is prerequisite to 240B.* Excitations and interactions in solids; crystal structures, symmetries, Bloch's theorem; energy bands; electron dynamics; impurity states; lattice dynamics, phonons; many-electron interactions; density functional theory; dielectric functions, conductivity and optical properties; excitons; electron-phonon interactions, polarons; Fermi surfaces; magnetoresistance; quantum Hall effect; transport processes, Boltzmann equation; superconductivity, BCS theory; many-body perturbation theory, Green's functions. (F) *Staff*

242A-242B. Theoretical Plasma Physics. (4;4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 142.* Analysis of plasma behavior according to the Vlasov, Fokker-Planck equations, guiding center and hydromagnetic descriptions. Study of equilibria, stability, linear and nonlinear electromagnetic waves, transport, and interaction with radiation. Rigorous kinetic theory. *Staff*

Most of these courses offer concentrated converage of their subject area, generally requiring substantial time for problem sets. It is not unusual for a student in electromagnetic theory, quantum, optics and cry-electonics, solid state, or plasmas to take roughly half of their graduate courses in physics.

6.1.4 Mathematics

(As a supplement to EECS Course Offerings)

Graduate work in EECS generally requires an advanced knowledge of mathematics. In this section, relevant math courses are summarized. See also the following section (entitled Applied Mathematics Courses Taught in Engineering) for 2 special courses on engineering analysis methods. There are 3 different levels of abstraction in the following listed courses. Undergraduate courses have the lowest, e.g., Math 120, which deals with the practical solution of physical problems. The next level of abstraction is found in the Math 220 series, graduate courses oriented toward engineering. Third level graduate courses in mathematics emphasize theory.

Upper Division Courses

104. Introduction to Analysis. (4) Three hours of lecture per week; at the discretion of the instructor, an additional two hours of discussion per week. *Prerequisites: 53 and 54.* The real number system. Sequences, limits, and continuous functions in R and R. The concept of a metric space. Uniform convergence, interchange of limit operations. Infinite series. Mean value theorem and applications. The Riemann integral. (F,SP) *Staff*

105. Second Course in Analysis. (4) Three hours of lecture per week. *Prerequisites: 104.* Differential calculus in Rn: the derivative as a linear map; the chain rule; inverse and implicit function theorems. Lebesgue integration on the line; comparison of Lebesgue and Riemann integrals. Convergence theorems. Fourier series, L2 theory. Fubini's theorem, change of variable. (SP)

113. Introduction to Abstract Algebra. (4) Three hours of lecture per week; at the discretion of the instructor, an additional two hours of discussion per week. *Prerequisites: 54 or a course with equivalent linear algebra content.* Sets and relations. The integers, congruences, and the Fundamental Theorem of Arithmetic. Groups and their factor groups. Commutative rings, ideals, and quotient fields. The theory of polynomials: Euclidean algorithm and unique factorizations. The Fundamental Theorem of Algebra. Fields and field extensions. (F,SP) *Staff*

121A-121B. Mathematical Tools for the Physical Sciences. (4;4) Three hours of lecture per week. *Prerequisites: 53 and 54.* Functions of a complex variable, Fourier series, finite-dimensional linear systems. Infinite-dimensional linear systems, orthogonal expansions, special functions, partial differential equations arising in mathematical physics. Intended for students in the physical sciences who are not planning to take more advanced mathematics courses. (F,SP)

125A. Mathematical Logic. (4) Three hours of lecture per week. *Prerequisites: 113 or consent of instructor.* Sentential and quantificational logic. Formal grammar, semantical interpretation, formal deduction, and their interrelation. Applications to formalized mathematical theories. Selected topics from model theory or proof theory. (F,SP)

128A. Numerical Analysis. (4) Three hours of lecture and one hour of discussion per week. At the discretion of instructor, an additional hour of discussion/computer laboratory per week. *Prerequisites: 53 and 54.*Programming for numerical calculations, round-off error, approximation and interpolation, numerical quadrature, and solution of ordinary differential equations. Practice on the computer. (F,SP)

128B. Numerical Analysis. (4) Three hours of lecture and one hour of discussion per week. At the discretion of the instructor, an additional hour of discussion/computer laboratory per week. *Prerequisites: 110 and 128A.*Iterative solution of systems of nonlinear equations, evaluation of eigenvalues and eigenvectors of matrices, applications to simple partial differential equations. Practice on the computer. (F,SP)

135. Introduction to the Theory of Sets. (4) Three hours of lecture per week. *Prerequisites: 113 and 104.* Set-theoretical paradoxes and means of avoiding them. Sets, relations, functions, order and well-order. Proof by transfinite induction and definitions by transfinite recursion. Cardinal and ordinal numbers and their arithmetic. Construction of the real numbers. Axiom of choice and its consequences. (F,SP)

185. Introduction to Complex Analysis. (4) Three hours of lecture per week; at the discretion of the instructor, an additional two hours of discussion per week. *Prerequisites: 104.* Analytic functions of a complex variable. Cauchy's integral theorem, power series, Laurent series, singularities of analytic functions, the residue theorem with application to definite integrals. Some additional topics such as conformal mapping. (F,SP) *Staff*

202A. Introduction to Topology and Analysis. (4) Three hours of lecture per week. *Prerequisites: 104.* Metric spaces and general topological spaces. Compactness and connectedness. Characterization of compact metric spaces. Theorems of Tychonoff, Urysohn, Tietze. Complete spaces and the Baire category theorem. Function spaces; Arzela-Ascoli and Stone-Weierstrass theorems. Partitions of unity. Locally compact spaces; one-point compactification. Introduction to measure and integration. Sigma algebras of sets. Measures and outer measures. Lebesgue measure on the line and Rn. Construction of the integral. Dominated convergence theorem. (F,SP)

202B. Introduction to Topology and Analysis. (4) Three hours of lecture per week. *Prerequisites: 202A and 110.* Measure and integration. Product measures and Fubini-type theorems. Signed measures; Hahn and Jordan decompositions. Radon-Nikodym theorem. Integration on the line and in Rn. Differentiation of the integral. Hausdorff measures. Fourier transform. Introduction to linear topological spaces, Banach spaces and Hilbert spaces. Banach-Steinhaus theorem; closed graph theorem. Hahn-Banach theorem. Duality; the dual of LP. Measures on locally compact spaces; the dual of C(X). Weak and weak-* topologies; Banach-Alaoglu theorem. Convexity and the Krein-Milman theorem. Additional topics chosen may include compact operators, spectral theory of compact operators, and applications to integral equations. (F,SP)

204A-204B. Ordinary and Partial Differential Equations. (4;4) Three hours of lecture per week. *Prerequisites: Graduate status or consent of instructor.* Fundamental existence theorem for ordinary differential equations. Properties of linear systems with constant and periodic coefficients. Sturm-Liouville theory; Poincare-Bendixson Theorem. Cauchy-Kowalewski theory for systems of partial differential equations. Initial and boundary value problems for elliptic, parabolic, and hyperbolic second order equations. Nonlinear equations and systems. Sequence begins Fall.

205. Theory of Functions of a Complex Variable. (4) Three hours of lecture per week. *Prerequisites: 185.* Normal families. Riemann Mapping Theorem. Picard's theorem and related theorems. Multiple-valued analytic functions and Riemann surfaces. Further topics selected by the instructor may include: harmonic functions, elliptic and algebraic functions, boundary behavior of analytic functions and HP spaces, the Riemann zeta functions, prime number theorem.

206. Banach Algebras and Spectral Theory. (4) Three hours of lecture per week. *Prerequisites: 202A-202B.*Banach algebras. Spectrum of a Banach algebra element. Gelfand theory of commutative Banach algebras. Analytic functional calculus. Hilbert space operators. C*-algebras of operators. Commutative C*-algebras. Spectral theorem for bounded self-adjoint and normal operators (both forms: the spectral integral and the "multiplication operator" formulation). Riesz theory of compact operators. Hilbert-Schmidt operators. Fredholm operators. The Fredholm index. Selected additional topics. (F)

207. Unbounded Operators. (4) Three hours of lecture per week. *Prerequisites: 206.* Unbounded self-adjoint operators. Stone's Theorem, Friedrichs extensions. Examples and applications, including differential operators. Perturbation theory. Further topics may include: unbounded operators in quantum mechanics, Stone-Von Neumann Theorem. Operator semigroups and evolution equations, some non-linear operators. Weyl theory of defect indices for ordinary differential operators.

215A-215B. Algebraic Topology. (4;4) Three hours of lecture per week. *Prerequisites: 113 and point-set topology (e.g. 202A).* Fundamental group and covering spaces, simplicial and singular homology theory with applications, cohomology theory, duality theorem. Homotopy theory, fibrations, relations between homotopy and homology, obstruction theory, and topics from spectral sequences, cohomology operations, and characteristic classes. Sequence begins fall.

219. Ordinary Differential Equations and Flows. (4) Three hours of lecture per week. *Prerequisites: 214.* Ordinary differential equations. Diffeomorphisms and flows on manifolds. Stable manifolds, generic properties, structural stability. Special topics selected by the instructor. (F)

Graduate Courses

221. Advanced Matrix Computations. (4) Three hours of lecture per week. *Prerequisites: Consent of instructor.* Direct solution of linear systems, including large sparse systems: error bounds, iteration methods, least square approximation, eigenvalues and eigenvectors of matrices, nonlinear equations, and minimization of functions. (F,SP)

222A-222B. Partial Differential Equations. (4;4) Three hours of lecture per week. *Prerequisites: 105 or 202B; 185.* The theory of initial value and boundary value problems for hyperbolic, parabolic, and elliptic partial differential equations, with emphasis on nonlinear equations. More general types of equations and systems of equations. Sequence begins fall.

224A-224B. Mathematical Methods for the Physical Sciences. (4;4) Three hours of lecture per week. *Prerequisites: Graduate status or consent of instructor.* Introduction to the theory of distributions. Fourier and Laplace transforms. Partial differential equations. Green's function. Operator theory, with applications to eigenfunction expansions, perturbation theory and linear and non-linear waves. Sequence begins fall. (F,SP)

225A-225B. Metamathematics. (4;4) Three hours of lecture per week. *Prerequisites: 125B and 135.* Metamathematics of predicate logic. Completeness and compactness theorems. Interpolation theorem, definability, theory of models. Metamathematics of number theory, recursive functions, applications to truth and provability. Undecidable theories. Sequence begins fall.

226A. Abstract Machines and Languages. (4) Three hours of lecture per week. *Prerequisites: 135; 114 or 113 and 110.* Finite state automata, regular sets, Turing machines, recursive functions, decision problems. Context-free languages, pushdown automata, ambiguity, special families of languages, power series in non-commuting variables.

227A. Theory of Recursive Functions. (4) Three hours of lecture per week. *Prerequisites: 225B.* Recursive and recursively enumerable sets of natural numbers; characterizations, significance, and classification. Relativization, degrees of unsolvability. The recursion theorem. Constructive ordinals, the hyperarithmetical and analytical hierarchies. Recursive objects of higher type. Sequence begins fall.

228A-228B. Numerical Solution of Differential Equations. (4;4) Three hours of lecture per week. *Prerequisites: 128A.*Ordinary differential equations: Runge-Kutta and predictor-corrector methods; stability theory, Richardson extrapolation, stiff equations, boundary value problems. Partial differential equations: stability, accuracy and convergence, Von Neumann and CFL conditions, finite difference solutions of hyperbolic and parabolic equations. Finite differences and finite element solution of elliptic equations.

245A. General Theory of Algebraic Structures. (4) Three hours of lecture per week. *Prerequisites: 113 and 135.* Structures defined by operations and/or relations, and their homomorphisms. Classes of structures determined by identities. Constructions such as free objects, objects presented by generators and relations, ultraproducts, direct limits. Applications of general results to groups, rings, lattices, etc. Course may emphasize study of congruence- and subalgebra-lattices, or category-theory and adjoint functors, or other aspects.

250A. Groups, Rings, and Fields. (4) Three hours of lecture per week. *Prerequisites: 114 or consent of instructor.* Group theory, including the Jordan-Holder theorem and the Sylow theorems. Basic theory of rings and their ideals. Unique factorization domains and principal ideal domains. Modules. Chain conditions. Fields, including fundamental theorem of Galois theory, theory of finite fields, and transcendence degree. (F)

250B. Multilinear Algebra and Further Topics. (4) Three hours of lecture per week. *Prerequisites: 250A.* Tensor algebras and exterior algebras, with application to linear transformations. Commutative ideal theory, localization. Elementary specialization and valuation theory. Related topics in algebra. (SP)

273. Topics in Numerical Analysis. Three hours of lecture per week. *Prerequisites: Consent of instructor.* Advanced topics chosen by the instructor. The content of this course changes, as in the case of seminars. (F,SP)

6.1.5 Applied Mathematics

(As a supplement to EECS course offerings)

117. Methods of Engineering Analysis. (3) Three hours of lecture and one hour of discussion per week. *Prerequisites: Mathematics 53, 54.* Methods of theoretical engineering analysis; techniques for analyzing partial differential equations and the use of special functions related to engineering systems. Sponsoring Department: Mechanical Engineering. (F) *Staff*

230A. Engineering Analysis. (3) Three hours of lecture and one hour of discussion per week. *Prerequisites: Graduate standing; Mathematics 53, 54.* Laplace transforms. Fourier series and integrals. Classification of partial differential equations. Linear analysis; operators, Green's functions. Sturm-Lieuville theory. Solutions of P.D.E. in rectangular domain. Bessel functions. Legrendre polynomials. Complex variables. Integration in complex plane. Sponsoring Department: Mechanical Engineering. (F) *Staff*

230B. Engineering Analysis. (3) Three hours of lecture per week. *Prerequisites: 230A.* Integral equations. Variational methods. Wiener-Hopf technique. Asymptotic expansion of integrals. Singularities and approximate and asympototic local solutions of ordinary differential equations. Regular and singular perturbations of ordinary and partial differential equations. (SP) *Staff*

6.1.6 Statistics

(As a supplement to EECS course offerings)

Due to the increasing use of statistics and stochastic modeling in EECS, some graduate students take Statistics 200AB unless this knowledge has been acquired elsewhere. Stat 205AB is a basic first course in probability theory devoted to probability measures, densities, expectations, etc., and requires about 2 years of calculus training. No prior probability knowledge is presumed but some limited prior exposure can be very useful.

EECS graduate students working with random phenomena (noise, queuing, etc.) may want to take additional courses in probability, statistics, and stochastic processes. Such courses are available in both the Industrial Engineering and Operations Research (IEOR) and the Statistics Departments. Courses in the Statistics Department fall mainly into 2 categories. The first (which includes Stat 200A) is concerned with probability theory or models and essentially ignores all statistical questions. The second category of courses presumes some probability theory and is devoted to aspects of the statistical inference from data theory, such as hypothesis testing, estimation of parameters, and similar topics.

6.2 Sample M.S. Programs

The following are sample programs for the M.S. degree. It is important to note that these are intended as suggestions only. Few students will elect to take precisely the courses indicated in any of these programs, and few will finish their coursework in exactly 2 semesters. You are free to devise any coherent program of study satisfying the coursework requirements of the M.S. degree, subject to the approval of your Advisor.

Caution: Be very careful not to overextend yourself in your first term of graduate study. It is very important to maintain a GPA of at least 3.0. Failure to do so in your first term can put you into a hole that is difficult to climb out of!

6.2.1 Electrical Engineering

Sample M.S. Program in Electromagnetics and Plasmas

(For students who have taken the equivalent of EE 117A, 130)

Fall Semester

EE210	Applied Electromagnetic Theory	3
	Electives*	7
EE299	Individual Research	2
EE298#	Either EM or Plasma Seminar	1
	Total	**13 Units**

Spring Semester

EE239	Partially Ionized Plasmas	3
	Electives*	7
EE299	Individual Research	2
EE298#	Either EM or Plasma Seminar	1
	Total	**13 Units**

*Suggested electives:
EM Emphasis: EE233, EE290e
IC Processing Emphasis: EE143, 243, 231, 290n, 290e
Plasma Emphasis: NE180, 280, 281, 290e, Phys142, 242ab
Dynamics Emphasis: Phys205ab, EE220

Sample M.S. Program in Quantum & Optical Electronics

(For students who have taken the equivalent of EE 117AB and Physics 137A, 130)

Fall Semester

EE210	Applied Electromagnetic Theory	3
EE236A	Quantum & Optical Electronics	3
EE232	Light wave Devices	3
EE299	Individual Research	2
EE298-5	Quantum Electronics Seminar	1
	Total	**12 Units**

Spring Semester

EE233	Light wave Systems	3
EE236B	Quantum & Optical Electronics	3
EE119	Intro. to Optical Engineering	3
EE299	Individual Research	2
EE298-5	Quantum Electronics Seminar	1
	And one of the following:	
EE231	Solid State Devices	3
EE230	Solid State Electronics	3
	Total	**12-15 Units**

Sample M.S. Programs in Bioelectronics

Fall Semester

EE221A	Linear System Theory	4
EE290J	Image Processing	3
EE299	Individual Research	2-3
	And one of the following:	
EE145L	Intro. Electronic Transducers Lab	2
EE146	Dynamic Networks in Biology	3
	Total	**12-13 Units**

Spring Semester

EE225A	Digital Signal Processing	3
EE246	Biological Systems	3
EE299	Individual Research	2
	And one of the following:	
EE145A	Sensors, Actuators, & Electrodes	4
EE145B	Computer Apps in Biology & Medicine	4
	Total	**12 Units**

Sample M.S. Programs for CAD (Computer Aided Design)

Accelerated Schedule—One Year Masters Program

Fall—Year 1

EE244	Intro. to CAD of Integrated Circuits	3
EE249	Design of Embedded Systems	4
	And one of the following:	
EE219A	Computer Aided Verification of Electronic Circuits & Systems	3
EE219C	Computer-Aided Verification	3
	Plus one of the following:	
EE299	Individual Research	2-3
EE290A	Advanced Topics in CAD	3
	Total	**12-13 Units**

Spring—Year 1

EE219B	Logic Synthesis for Hardware Systems	4
EE241	Advanced Digital Integrated Circuits	3
	And one of the following:	
EE225A	Digital Signal Processing	3
EE225	CVLSI Signal Processing	3
	Plus one of the following:	
EE299	Individual Research	2-3

EE290A	Advanced Topics in CAD	3
	Total	**12-13 Units**

Typical Schedule - 3 Semester Master's Program

Fall—Year 1

EE244	Intro. to Computer Aided Design of Integrated Circuits	3
EE290A	Advanced Topics in CAD	3
EE299	Individual Research	3
	And one of the following:	
EE219C	Computer-Aided Verification	3
EE219A	Computer Aided Verification of Electronic Circuits & Systems	3
CS170	Efficient Algorithms & Intractable Problems	4
	Total	**12-13 Units**

Spring—Year 1

EE219B	Logic Synthesis for Hardware Systems	4
EE290A	Advanced Topics in CAD	3
EE299	Individual Research	2-3
	And one of the following:	
EE241	Advanced Digital Integrated Circuits	3
EE225A	Digital Signal Processing	3
EE225C	VLSI Signal Processing	3
	Total	**12-13 Units**

Fall—Year 2

EE249	Design of Embedded Systems	4
EE290A	Advanced Topics in CAD	3
EE299	Individual Research	2-3
	And one of the following:	
EE219A	Computer Aided Verification of Electronic Circuits & Systems	3
EE219C	Computer-Aided Verification	3
CS170	Efficient Algorithms & Intractable Problems	4
EE225A	Digital Signal Processing	3
EE225C	VLSI Signal Processing	3
	Total	**12-14 Units**

Sample M.S. Program for IC Processing

Fall Semester

E143	Processing & Design of Integrated Circuits	4
EE130	Integrated-Circuit Devices	4
EE141	Intro. to Digital Integrated Circuits	3
EE299	Individual Research	2
	Total	**13 Units**

Spring Semester

EE243	Advanced IC Processing & Layout	3
EE231	Solid-State Devices	3
EE241	Advanced Digital Integrated Circuits	3
EE299	Individual Research	3

	Total	**13 Units**

Sample M.S. Programs for Solid-State Devices

Fall Semester

EE130	Integrated Circuit Devices	4
EE299	Individual Research	1
	And one of the following:	
EE141	Digital Integrated Circuits	4
EE140	Linear Integrated Circuits	4
	Plus one of the following:	
EE143	Processing & Design of Integrated Circuits	4
EE230	Solid State Electronics	3
	Total	**12-13 Units**

Spring Semester

EE231	Solid State Devices	4
EE299	Individual Research	3
	And one of the following:	
EE241	Advanced Digital Integrated Circuits	3
EE243	Advanced Integrated Circuit Process & Layout	3
	Plus one of the following:	
EE233	Light Wave Systems	3
EE245	Intro. to MEMD Design	3
	Total	**13 Units**

Sample M.S. Programs for Computer Integrated Manufacturing

Fall Semester

CS186	Intro. to Database Systems	4
EE143	Processing & Design of Integrated Circuits	4
EE299	Individual Research	2
	And one of the following:	
EE241	Advanced Digital Integrated Circuits	3
EE231	Solid State Devices	3
	Total	**13 Units**

Spring Semester

STAT135	Concepts of Statistics	4
EE243	Advanced Integrated Circuits Processing & Layout	3
EE244	Computer Aided Design of Integrated Circuits	3
EE299	Individual Research	3
	Total	**13 Units**

Fall—Year 2

EE290W	Special Issues in Semiconductor Mfg.	3
EE290N	Integrated Circuit Technology Design	3
EE299	Individual Research	4
	And one of the following:	
IDS296	Management of Innovation & Policy	3
CS287	Advanced Robotics	3
IEOR165	Forecasting, Quality Control & Assurance	
IEOR215	Analysis & Design of Databases	3
	Total	**13 Units**

Sample M.S. Programs for Solid-State Sensors and Actuators

Fall Semester

EE143	Processing & Design of Integrated Circuits	4
EE230	Solid State Electronics	3
EE290G	Microsensors & Microactuators	2
EE299	Individual Research	3
	Total	**12 Units**

Spring Semester

EE231	Solid-State Devices	3
EE299	Individual Research	3
	Electives*	6
	Total	**12 Units**

*Electives can be chosen from a wide variety of courses offered according to student interest and need. Courses in EE that are especially relevant to the subject area are those in integrated circuits, plasmas, quantum electronics and superconductivity. Courses in Materials Science, Mechanical Engineering, Chemical Engineering, Physics and Bioengineering may also hold special interest. In addition to the Graduate Information Manual, consult the General Catalog, as well as advisors in the general field.

Sample Program in Integrated Circuits

Fall Semester

EE140	Linear Integrated Circuits	3
EE141	Digital Integrated Circuits	4
	Electives	5
	Total	**12 Units**

Spring Semester

EE240	Advanced Analog Integrated Circuits	3
EE241	Advanced Digital Integrated Circuits	3
EE299	Individual Research	3
	Electives	3
	Total	**12 Units**

Sample Program in Control

Fall Semester

EE221A	Linear System Theory	4
EE226A	Random Processes in Systems	4
EE298-14	Control Seminar	1
	And one of the following:	
EE122	Communication Networks	2
EE125	Introduction to Robotics	4
EE291E	Hybrid Control Systems	

	Total	**11-13 Units**

Spring Semester

EE222	Nonlinear Systems: Analysis, Stability & Control	3
CS298-4	AI Robotics & Vision Seminar	4
EE299	Individual Research	3
	And one of the following:	
EE223	Stochastic Systems: Estimation & Control	3
EE227A	Optimization Techniques	3
ME235	Switching Control & Computer Interfacing	3
ME234	Multivariable Control System Design	3
	Plus one of the following:	
EE291E	Hybrid & Hierarchical Systems	3
CS280	Computer Vision	3
	Total	**16 Units**

Sample Program in Circuits and Networks

Fall Semester

EE219	Circuit Theory & Computer Aided Analysis	3
EE221A	Linear System Theory	4
EE226A	Random Processes in Systems	4
EE299	Independent Research	1
	Total	**12 Units**

Spring Semester

EE222	Nonlinear Systems-Analysis, Stability & Control	3
EE225A	Digital Signal Processing	3
EE299	Independent Research	3
	And one of the following:	
EE227A	Optimization Techniques	3
EE244	Computer-Aided Design of Integrated Circuits	3
	Total	**12 Units**

Sample Program in Mechatronics

Fall Semester

EECS221A	Linear System Theory	4
EECS125	Introduction to Robotics	4
EE245	Introduction to MEMD Design	3
EE299	Independent Research	2
	And one of the following:	
EE145M	Introductory Microcomputer Interfacing Laboratory	2
ME230	Real-Time Applications of Mini & Micro Computers	4
	Total	**15-17 Units**

Spring Semester

EECS192	Mechatronic Design Lab	3
EE225A	Digital Signal Processing	3
EE299	Independent Research	1
ME235	Switching Control & Computer Interfaces	4
	And one of the following:	
CS184	Foundations of Computer Graphics	4
EECS222	Nonlinear Systems Analysis, Stability, & Control	3

EE291E	Hybrid Control Class	4
	Total	**14-15 Units**

Sample Program in Communications

Fall Semester

EE221A	Linear System Theory	4
EE226A	Random Processes in Systems	4
EE299	Independent Research	1-2
	And one of the following:	
EE228A	High Speed Communications Networks	3
EE122	Intro. to Communication Networks	2
	Total	**11-13 Units**

Spring Semester

EE224	Digital Communication	3
EE299	Independent Research	6
	And one of the following:	
EE223	Stochastic Systems: Estimation & Control	3
EE229	Information Theory & Coding	3
EE225A	Digital Signal Processing	3
	Total	**12 Units**

Sample Program for Signal Processing

Fall Semester

EE123	Digital Signal Processing	4
EE225B	Multi Dimensional Signal Processing	3
EE226A	Random Processes in Systems	4
EE299	Independent Research	1
	Total	**12 Units**

Spring Semester

EE221A	Linear System Theory	4
EE225A	Digital Signal Processing	3
EE299	Independent Research	2
	And one of the following:	
EE224	Digital Communication	3
EE223	Stochastic Systems	3
	Total	**12 Units**

Sample Program for Robotics

Fall Semester

EE221A	Linear System Theory	4
EE125	Introduction to Robotics	4
CS298-4	Graphics, Vision & Robotics Seminar	1
	And one of the following:	
CS184	Foundations of Computer Graphics	4
CS188	Intro. to Artificial Intelligent	4

		Total	**13 Units**

Spring Semester

EE192	Mechatronic Design Lab		2
CS287	Advanced Robotics		3
EE222	Nonlinear Control		3
CS280	Computer Vision		3
EE299	Individual Research		3
		Total	**14 Units**

6.2.2 Computer Science

Sample M.S. Program for Computer Architecture & Hardware

(For students who have taken the equivalent of CS, 152, EE140)

Fall Semester

CS252	Graduate Computer Architecture		3
CS250	VLSI Systems Design		4
CS162	Operating Systems & System Programming		4
CS299	Individual Research		3
		Total	**14 Units**

Spring Semester

CS254	Topics in VLSI Chip Design & Implementation		4
EE299	Individual Research		4
	And one of the following:		
CS257	Advanced Computer Architecture		3
CS258	Parallel Processors		3
CS262	Advanced Topics in Operating Systems		4
CS267	Applications of Parallel Computers		3
		Total	**12-11 Units**

Sample M.S. Program for Database Management Systems

(For students who have had the equivalent of CS152, 162, 164)

Fall Semester

CS186	Introduction to Database Systems		3
CS262A	Advanced Topics in Operating Systems		3
CS268	Computer Networks		3
	And one of the following:		
EECS122	Introduction to Communication Networks		3
CS299	Individual Research		3
CS188	Introduction to AI & Natural Language Processing		4
		Total	**12-13 Units**

Spring Semester

CS262B	Advanced Topics in Computer Systems		3
CS286	Implementation of Database Systems		3
CS299	Individual Research		4
	Electives		3-4
		Total	**13-14 Units**

Sample M.S. Program for Computer Graphics

Fall Semester

CS170	Efficient Algorithms & Intractable Problems	4
CS184	Foundations of Computer Graphics*	4
CS284	Computer-Aided Geo. Design & Modeling	3
CS299	Individual Research	2
	And one of the following:	
CS285	Solids Modeling	3
CS280	Computer Vision	3
	Total	**13-16 Units**

*If you have had a CS184 equivalent, take CS284 and CS285 whenever they are offered, since they may not be offered every year. Also, get involved with a research project as soon as possible.

Following Semesters—Take 1-2 courses per semester from this list, doing a minimum of 12 units per semester

CS260	User Interfaces to Computers	3
CS264	Implementation of Programming Lang	4
CS274	Computational Geometry	3
CS280	Computer Vision	3
CS284	Computer-Aided Geometric Design & Modeling	3
CS285	Solids Modeling	3
CS286	Implementation of Database Systems	3
CS28	Advanced Robotics	3
CS288	AI Approach to Natural Language Processing	3
CS294	Special topics courses offered (e.g. Rendering)	3
CS299	Individual Research	3+

Sample M.S. Program for Human-Computer Interface (HCI)

Fall Semester

CS160	User Interface Design, Prototyping & Evaluation*	4
CS260	Research Topics in Human-Computer Interface	3
CS294-4	Human-Centered Computing	3
CS299	Individual Research	2-3
	Total	**12-13 Units**

*If you have had a CS160 equivalent, take CS260 and CS294-4 (HCC) whenever they are offered, since they may not be offered every year. Also, get involved with a research project as soon as possible.

Spring Semester-- Take 1-2 courses per semester from this list, doing a minimum of 12 units per semester

CS294-3	Digital Documents and Services	3
SIMS290	Computer-Mediated Communication	3
SIMS214	Needs Assessment and Evaluation of Information Systems	3
SIMS247	Information Visualization & Presentation	3
SIMS271	Quantitative Research Methods for Information Management	3
CS280	Computer Vision	3
CS188	Introduction to AI & Natural Language Processing	4
CS288	AI Approach to Natural Language Processing	3
CS281B	Advanced Topics in Learning & Decision Making	3

CS294-5	Statistical Learning Theory	3
CS184	Computer Graphics	4
CS284	Computer-Aided Geometric Design & Modeling	3
CS262	Advanced Topics in Operating Systems	3
CS294	Special topics courses offered (e.g. CSCW)	3
CS299	Individual Research	3+

Sample M.S. Program for Programming Languages

Fall Semester

CS164	Programming Languages and Compilers	4
CS162	Operating Systems & System Programming	4
	And one of the following:	
CS170	Efficient Algorithms & Intractable Problems	4
CS150	Components & Design Techniques for Digital Systems	5
	Total	**12-13 Units**

Spring Semester

CS264	Implementation of Programming Languages	4
CS262	Advanced Topics in Operating Systems	4
CS252	Graduate Computer Architecture	4
	Total	**12 Units**

Fall—Year 2

CS263	Design of Programming Languages	3
CS265	Advanced Programming Languages Implementation	3
CS299	Individual Research	4
CS292,294	Special Topics	3
	Total	**13 Units**

Sample M.S. Program for Operating Systems

(For students who have had the equivalent of CS, 162, and 170)

Fall Semester

CS152	Computer Architecture & Engineering	5
CS262	Advanced Topics in Operating Systems	4
CS164	Programming Languages & Compilers	4
CS299	Individual Research	2
	Total	**15 Units**

Spring Semester

CS252	Graduate Computer Architecture	4
CS267	Applications of Parallel Computers	3
CS268	Computer Networks	3
CS299	Individual Research	1
CS300	TA Software Engineering (CS169)	3
	Total	**14 Units**

*also recommended are CS 260, 264, 270, 284 or 286

Sample M.S. Program for Theory of Computation

(For those students who have had the equivalent of CS, 152, 170, 172)

Fall Semester

CS174	Combinatorics & Discrete Probability	3
CS270	Combinatorial Algorithms & Data Structures	3
CS274	Computational Geometry	3
CS299	Individual Study	3
	Total	**12 Units**

Spring Semester

CS273	Foundations of Parallel Computing	3
CS276	Number Theory & Cryptography	2
CS278	Machine-Based Complexity Theory	3
CS299	Individual Research	4
	Total	**12 Units**

6.3 Management of Technology Joint Program

The College of Engineering and the School of Business Administration have developed a joint curriculum for those graduate students interested in R&D management. It contains new courses covering product development and manufacturing management, as well as the economics of technology and governmental policy. Related courses in Engineering and Business Administration complete the curriculum. With the approval of the Advisor, these courses may be included in MS and Ph.D. programs and may constitute a minor in the latter. Details on the program are available from Engineering/Interdisciplinary Studies in 230 Bechtel Hall.

6.4 Designated Emphasis

Doctoral students in many science programs at UC Berkeley now have the opportunity to pursue a specialization and receive recognition for it when awarded their degree. There are currently 3 of these "designated emphasis" programs (DE's) within the College of Engineering.

- Designated Emphasis in Communication, Computation and Statistics[1]
- Designated Emphasis in Computational and Genomic Biology[2]
- Designated Emphasis in Nano scale Science and Engineering[3]
- Designated Emphasis in New Media[4]

6.4.1 Admission Procedures for the DE

Before taking the qual exam, complete an application for admission to the appropriate Designated Emphasis program, and return it to your Graduate Assistant. Forms are available online and in the Graduate Matters Office.

[1] http://www.eecs.berkeley.edu/CCS/
[2] http://computationalbiology.berkeley.edu/
[3] http://nano.berkeley.edu/nanosite/
[4] http://cnm.berkeley.edu/instruction/degrees.php

Once approved, a Change of Major or Degree Goal petition will be filed with the Degrees Unit, 318 Sproul Hall, to indicate your admission into the DE. Upon receipt of the appropriately signed petition, the addition of the DE will be entered into the Graduate Division and Registrar's databases. When you file your dissertation, the DE will appear on the degrees list and be entered into your transcript in the Registrar's office as awarded.

Graduate Assistants have further information.