951A. Field Research Methods in Education
(ED 961, E 920, EAC 951A.)
Spring, 3 credits. Methods of interview, participant observation, or observation for carrying on educational research.

951B. Theories, rationales, and principles of governance, management, and instruction in post-secondary educational institutions. Emphasis upon personnel and student administration and equity issues.

951C. Higher Education Finance
(ED 970, EAC 970A.) Fall, Spring, 3(3-0) Admission to M.A. or Ph.D. programs in the College of Education.

952A. Multidisciplinary Seminar in Educational Administration
(ED 973, EAC 973A.) Fall, Spring, 3 credits. May reenroll for a maximum of 9 credits. Emphasis on special problems in education.

952B. Adult Education: Program Planning
Spring, 3(0-6) EAD 960, EAD 986.

953A. College Student Affairs Administration I
(ED 973A, EAC 973A.) Fall, 3(3-0) Doctoral students in Student Affairs Emphasis. Approval of instructor.

953B. College Student Affairs Administration II
(ED 974, EAC 974A.) Winter, 3(3-0) Doctoral students in Student Affairs Emphasis. Approval of instructor.

954. Seminar: Continuing Education in Higher Education Institutions
(ED 975, EAC 975A.) Semester, 1 to 6 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration, approval of instructor.

955. Phylogenetic Problems
(ED 976, EAC 976A.) Fall, Spring, 3(3-0) May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration, approval of instructor.

956. Community College Administration
(ED 977, EAC 977A.) Winter, 3(3-0) Doctoral students in College and University Administration. Approval of instructor.

957. Management Systems in Higher Education Administration
(ED 978, EAC 978A.) Fall, Spring, 3(3-0) Doctoral students in College and University Administration; others, approval of instructor.

958. Laboratory and Field Experience in Administration and Curriculum
(ED 979, EAC 979A.) Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

960. Doctoral Dissertation Research
(ED 980, EAC 980A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

970A. The Law of Higher Education
(ED 980, EAC 980A.) Fall, Spring, 3(3-0) Graduate students in College and University Administration; others, approval of instructor.

970B. Higher Education Finance
(ED 970B, EAC 970B.) Fall, Spring, 3(3-0) Doctoral students in Student Affairs Emphasis. Approval of instructor.

970C. Evaluation of Higher Education
(ED 970C, EAC 970C.) Spring, 3(3-0) Doctoral students in College and University Administration; others, approval of instructor.

971A. The Department in Higher Education
(ED 971A, EAC 971A.) Winter, 3(3-0) Doctoral students in College and University Administration; others, approval of instructor.

971B. Management Systems in Higher Education Administration
(ED 971B, EAC 971B.) Fall, Spring, 3(3-0) Doctoral students in College and University Administration; others, approval of instructor.

971C. Community College Administration
(ED 971C, EAC 971C.) Winter, 3(3-0) Doctoral students in College and University Administration. Approval of instructor.

972A. Seminars in Administration and Curriculum
(ED 973A, EAC 973A.) Fall, Winter, Spring, 1 to 9 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

973A. College Student Affairs Administration I
(ED 973A, EAC 973A.) Fall, 3(3-0) Doctoral students in Student Affairs Emphasis. Approval of instructor.

973B. College Student Affairs Administration II
(ED 973B, EAC 973B.) Winter, 3(3-0) Doctoral students in Student Affairs Emphasis. Approval of instructor.

974. Laboratory and Field Experience in Administration and Curriculum
(ED 974, EAC 974A.) Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

975. Doctoral Dissertation Research
(ED 975, EAC 975A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

976A. Doctoral Internship in College and University Administration
(ED 981, EAC 981A.) Fall, Winter, Spring, Summer. 3(3-0) May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration, approval of instructor.

977A. Independent Research in Higher Education Administration
(ED 982, EAC 982A.) Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

978. Seminars in Administration and Curriculum
(ED 980, EAC 980A.) Fall, Winter, Spring, Summer. 1 to 9 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

979. Doctoral Dissertation Research
(ED 981, EAC 981A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

980. Laboratory and Field Experience in Administration and Curriculum
(ED 982, EAC 982A.) Fall, Winter, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

981. Doctoral Dissertation Research
(ED 982, EAC 982A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

982. Seminars in Administration and Curriculum
(ED 983, EAC 983A.) Fall, Winter, Spring, Summer. 1 to 9 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

983. Seminars in Administration and Curriculum
(ED 984, EAC 984A.) Fall, Winter, Spring, Summer. 1 to 9 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

984. Laboratory and Field Experience in Administration and Curriculum
(ED 985, EAC 985A.) Fall, Winter, Spring, Summer. 1 to 9 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

985. Doctoral Dissertation Research
(ED 986, EAC 986A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

986. Laboratory and Field Experience in Administration and Curriculum
(ED 987, EAC 987A.) Fall, Winter, Spring, Summer. 1 to 9 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

987. Doctoral Dissertation Research
(ED 988, EAC 988A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

988. Laboratory and Field Experience in Administration and Curriculum
(ED 989, EAC 989A.) Fall, Winter, Spring, Summer. 1 to 9 credits. May reenroll for a maximum of 12 credits. Doctoral students in College and University Administration.

989. Doctoral Dissertation Research
(ED 990, EAC 990A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

990. Doctoral Dissertation Research
(ED 991, EAC 991A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

991. Doctoral Dissertation Research
(ED 992, EAC 992A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

992. Doctoral Dissertation Research
(ED 993, EAC 993A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

993. Doctoral Dissertation Research
(ED 994, EAC 994A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

994. Doctoral Dissertation Research
(ED 995, EAC 995A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

995. Doctoral Dissertation Research
(ED 996, EAC 996A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

996. Doctoral Dissertation Research
(ED 997, EAC 997A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

997. Doctoral Dissertation Research
(ED 998, EAC 998A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

998. Doctoral Dissertation Research
(ED 999, EAC 999A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

999. Doctoral Dissertation Research
(ED 999A, EAC 999A.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

Electrical Engineering and Systems Science — Descriptions of Courses

College of Engineering

Electrical Engineering
EE

230. Digital Logic Fundamentals
Fall, Winter, Spring, Summer. 4(4-0) CPS 112 or CPS 251

- Boolean algebra; combinational logic and minimization; sequential system fundamentals and components; arithmetic operations and devices; memory devices and ensembles; data conversion principles; digital integrated circuits; practical engineering design problems.
Descriptions — Electrical Engineering and Systems Science of Courses

231. Computer Organization and Usage
Fall, Winter. Spring. 4(4-0) E E 230.
Computer structure and machine language; macros; addressing techniques; computer bus; program segmentation and linkage; microcomputer case study; survey of applications in science and engineering.

300. Electric Circuits I
Fall, Winter. 4(4-0) MTH 113.

301. Electric Circuits II
Winter, Spring. 3(3-0) E E 300, MTH 214.
Sinusoidal steady state response. Average power and rms concepts, complex frequency response, Two-port networks. Transfer functions.

302. Basic Electronic Circuits
Spring, Summer. 4(4-0) E E 301, MTH 215.
Volts-ampere characteristics of diodes and transistors. Voltage, current and power amplification. Stability, transient and high-frequency effects. Feedback, oscillators and operational amplifiers.

303. Electronics Laboratory I
Winter, Spring. 1(0-3) E E 300; E E 301 concurrently.
Electronic test equipment and measurement fundamental. Experimental verification of topics covered in E E 300 and E E 301. Computer-aided circuit analysis and design.

304. Electronics Laboratory II
Fall, 1(0-3) E E 302.

305. Electromagnetic Fields and Waves I
Fall, Winter. 3(3-0) MTH 310, PHY 288.
Vector analysis, Electrostatic fields, EM sources, scalar potential, Poisson's and Laplace's equations, dielectric media, capacitance, and energy storage. Boundary value problems for electrostatic fields.

306. Electromagnetic Fields and Waves II
Winter, Spring. 3(3-0) E E 305.
Electromagnetic fields; EM sources, vector potential, magnetic media, inductance; energy storage-time varying fields, and Maxwell's equations; potential theory and boundary value problems.

307. Electromagnetic Fields and Waves III
Spring, Summer. 3(3-0) E E 306.
Application of Maxwell's equations; radiation, propagation, reflection, and power flow of plane EM waves; EM boundary value problems. Transmission line theory; transient and steady state waves, standing and traveling waves, reflections and standing-wave-ratio.

308. Fields and Waves Laboratory
Fall, Spring. 1(0-3) E E 307 or concurrently.
Experimental investigation of charged particle motion in EM fields, dielectric and magnetic properties and materials, probing of currents and charges, and propagation of transient and steady-state waves. Digital computer solutions for EM field and wave problems.

320. Electromechanical Energy Conversion
Fall, Spring. 3(3-0) E E 301, E E 306.
Review of electromagnetics, three phase power, transformers, electromechanical energy conversion, basic concepts of rotating machines, alternating current machines.

345. Introduction to Electronic Instrumentation Systems
Fall, Winter. Spring. 4(3-3) PHY 288.
Basic electronic concepts: passive and active components; operational amplifiers; switching devices, equivalent circuits; transducers; signal conditioning; recording; data management; basic elements of control.

355. Deterministic Communication Systems
(FPHY) Fall, Spring. 3(3-0) E E 301, MTH 214. Interdepartmental with Systems Science.
Communication systems. Representation of signals in time and frequency domain. Processing of signals by linear, simple nonlinear and time-variant systems. Linear and nonlinear, analog and digital modulation; and demodulation; for example, AM, FM, PCM.

412. State Models, Analysis, and Simulation
Spring. 3(3-0) SYS 311, MTH 310, MTH 334. Interdepartmental with and administered by Systems Science.
Vector-matrix state-space models of dynamic systems, exponential matrix, transform solutions, convolution, stability, controllability, observability, simulation, computational techniques, extensions to nonlinear systems.

413. Analysis of Control Systems
(313.) Fall. 4(4-0) E E 301, E E 355. Interdepartmental with and administered by Systems Science.
Control system characteristics, performance criteria, transient and steady-state responses, error analysis, stability, root locus and frequency response techniques. Controller design using root locus and frequency response methods.

414. Control Systems Laboratory
Experimental investigations of feedback systems. Study of solid state controllers. Properties and applications of phase lock loops. Introduction to digital control.

415. Digital Control Systems
Winter. 3(3-0) E E 321, SYS 311, SYS 413. Interdepartmental with Systems Science.
Organization of digital control systems, classical and modern techniques for the design of digital control systems. Hardware and software considerations with emphasis on microprocessor implementation.

418. Introduction to Computer-Aided Circuit Design
Fall. 3(3-0) CPS 301, E E 302.
Introduces the techniques used for automatic formulation, analysis and optimization of linear and nonlinear electronic circuits. Students will write a modest but useful analysis program package.

419. Physical Phenomena and Electronic Instrumentation I
Winter. 4(3-3) PHY 289, PHY 298 or approval of department, MTH 215. Interdepartmental with and administered by Physics.
Concepts of electronics relative to the use in investigations of physical phenomena and their subsequent applications to provide reliable instrumentation. Nuclear radiation detectors, photometers and magnetometers are examples of specific topics covered.

421. Power System Analysis
Spring. 3(3-0) E E 307, E E 420.
Model of power system components; analysis and planning techniques including load flow, short circuit, transient stability; voltage and frequency control; economic operation of power systems.

422. Power Electronics
Winter. 3(3-0) E E 302, E E 320.
Thyristor characteristics, commutation, AC voltage controllers, single-phase and three-phase rectifier and inverter circuits, DC-to-DC converters, cycloconverters, AC and DC motor drives.

423. Electrical Machines Laboratory
Spring. 1(0-3) E E 320.
Transformers, torque, power and speed characteristics of induction, synchronous and dc machines, steady-state and transient operation of machines, machine control.

430. Digital Electronics
Fall, Winter, Spring. 3(2-3) E E 230, E E 302.
Diodes and transistors as switching elements; logic families, data conversion circuits; memory circuits; digital subsystem design.

431. Computer Interfacing
Fall, Winter. Spring. 4(3-3) E E 311; E E 430.
Case study of a small computer system; I/O controller design; bus interface requirements, interrupt structure, and data transfer. Digital system design.

435. Microwave Circuits and Systems
Fall. 3(3-0) E E 207.

436. Radiation and Reception of Electromagnetic Waves
Winter. 3(3-0) E E 207.
Radiation, propagation, scattering and reception of electromagnetic waves; circuit and radiation characteristics of wire and microwave and antennas; radiation fields, self and mutual impedances of antennas and arrays; microwave apertures.
438. Transmission and Radiation Laboratory
Fall, Winter. 3(3-0) E E 435; E E 436 concurrently.
Microwave transmission and radiation laboratory. Measurement of frequency, wavelength, standing waves, impedance, and power. Experiments on transmission lines, waveguides, cavity resonators, microwave circuits, and circuit and radiation properties of antennas.

456. Applied Probability in Communication Theory
Fall, Winter. 3(3-0) E E 355.

457. Statistical Communication Systems
Spring. 3(3-0) E E 456; E E 467 concurrently.
Representation, processing and filtering of random signals. Performance of digital systems with noise. Optimal digital communications systems. Signal detection, information concepts, coding and decoding. Communication systems such as radar, television, PCM, and telephony.

487. Communications Laboratory
Fall, Winter. 3(3-0) E E 456; E E 457 concurrently.
Experimental investigations on communication theory and information transmission topics from E E 455, E E 456, and E E 457.

474. Physical Principles of Electronic Devices
Fall. 4(4-0) E E 302; E E 305.
Energy levels in atoms and crystals, density of states, Fermi-Dirac and Maxwell-Boltzmann statistics, transport properties of bulk materials, metal-semiconductor contacts; the p-n junction and BJTs.

475. Electronic Devices and Circuits
Fall, Winter. 3(3-0) E E 474.
Fabrication technology; models and characteristics of BJTs, JFETs, and MOS devices; application to linear and digital circuits.

476. Applications of Electronic Devices
Spring. 3(3-0) E E 474.
Power devices and applications; transistors, diodes, triacs, and SCR's; high frequency devices and applications; transistors; impact, Gunn and vacuum devices; photo-device; solar cells and LED's.

477. Electro-optic Devices
Spring of odd-numbered years. 3(3-0) E E 308.
Atomic origin and the operational characteristics of light sources and detectors. Basic design considerations for gas and solid state lasers. Methods of optical detection, applications.

478. Integrated Circuit Fabrication Laboratory
Winter, Spring, Summer. 2(1-3) E E 474.
Integrated circuit design and fabrication. Laboratory fabrication of diffused resistors, diodes, capacitors, and simple MOS or bipolar integrated circuits. Yields, testing, and economical considerations.

480. Integrated Circuits: Operational Amplifiers
Fall, Winter. 3(3-0) E E 302.

490. Special Topics in Electrical Engineering
Spring. 1 to 4 credits. May reenroll for a maximum of 4 credits. Approval of department.
Exposition of special topics in electrical engineering.

495. Independent Study
Fall, Winter, Spring. Summer. 1 to 3 credits. May reenroll for a maximum of 3 credits in E E 495 and E E 496 and E E 447.
Independent study of a topic in electrical engineering of particular interest to the student.

499. Undergraduate Research
Fall, Winter, Spring. Summer. 1 to 3 credits. May reenroll for a maximum of 6 credits in E E 498 and E E 499 combined. Approval of department.
Independent undergraduate research in contemporary areas of electrical engineering such as: alternative energy, monitoring and control, bioengineering, power systems, integrated electronics, electromagnetic theory.

801. Special Problems
Fall, Winter, Spring. Summer. 1 to 4 credits. Approval of department.
Investigation of a topic in electrical engineering compatible with the student's prerequisites, interest, and ability.

809. Computer Arithmetic Algorithm Design
Fall. 4(4-0) E E 421 or E E 423, Interdepartmental with the Department of Computer Science.
Number systems; fast two-operaor and multiply/divider addition/subtraction; standard, recoded and cellular array multipliers; high-performance dividers; floating-point arithmetic; error control; pipelining.

812. Computer Networks
Spring. 3(3-0) E E 421. Interdepartmental with and administered by the Department of Computer Science.
Network architecture model, routing and congestion control, satellite and radio networks, local computer networks, virtual terminal and file transfer protocols, network security, transport and session protocols, distributed processing.

813. Logic Design Methodologies
Spring. 3(3-0) E E 423 or E E 431. Interdepartmental with the Department of Computer Science.
Modeling and simulation of logic circuits; hardware description languages; design methodologies for logic arrays and bit-slice processors; fault tolerance, testability, computer-aided design of logic circuits; automated routing algorithms.

815. Architecture of Computational Systems
Fall, Winter. 3(3-0) E E 423. Interdepartmental with and administered by the Department of Computer Science.
Overview of computer system organization; theoretical constructs of computer systems; processors, control units; memory; interconnection networks.

818. Introduction to Robotics
Spring. 3(3-0) E E 415 or E E 458 or approval of department. Interdepartmental with the Department of Computer Science.
Robot configuration and geometry. Robot drive systems, kinematics, controller design, sensors, sensor-based robots. Economic, political and social implications. Industrial application.

820. Electric Power Transmission System
Spring of odd-numbered years. 4(4-0) E E 421 or approval of instructor.
Symmetrical components, calculation of short circuit currents for symmetrical and unsymmetrical faults; methods and devices used in protection; pilot wire and carrier systems, circuit interruption, grounding.

823. Power System Stability and Control
Fall of even-numbered years. 3(3-0) E E 426.
Analysis and simulation of small and large disturbances stability of power systems; generator, exciter, voltage regulator models; design of excitation systems and power system stabilizers.

824. Power System Operation and Control
Fall of odd-numbered years. 3(3-0) E E 423, E E 456 or E E 490 or 447.
Operation planning of power systems including load flow, unit commitment, and production cost methods; on-line operation and control including automatic generation control, economic dispatch, security assessment, and state estimations.

826. Advanced Linear Systems Analysis
Fall. 4(4-0) MTH 310, MTH 334, approval of instructor. Interdepartmental with and administered by the Department of Mathematics.
Analysis of linear continuous time and discrete time systems for both time invariant and time varying models; state space and transfer function models; transition matrices; controllability; observability; minimal realizations; stability.

831. Active Network Synthesis
Winter. 3(3-0) Approval of department.

832. Switched Capacitor Circuits
Spring of even-numbered years. 3(3-0) E E 480.
Switched capacitor analog circuit analysis and design. Analog sampled data concepts; implementation of signal processing operations; switched capacitor filters; nonideal effects; linear and nonlinear applications.

Electrical Engineering and Systems Science — Descriptions of Courses

A-69
835. Electromagnetic Theory
Fall. 3(3-0). Approval of department.

Electromagnetic Waves I
Winter. 3(3-0) E E 835.

Electromagnetic Waves II
Spring. 3(3-0) E E 836.

841. Fourier Optics
Spring of even-numbered years. 3(3-0)
E E 455 or E E 880. E E 307 or E E 835.
Electromagnetic (Fourier) optics and optical information processing. Spatial linear systems. Electromagnetic theory of scalar diffraction: lenses; optical imaging systems; optical information processing; holography.

845. Detection and Estimation Theory
Spring of odd-numbered years. 3(3-0)
SYS 863.
Classical detection theory, hypothesis testing, decision criteria, multiple hypothesis, colored noise, detection of signals with known parameters. Bayes estimates, MAP, ML, LMSSE, Wiener and Kalman filters, nonlinear estimation, application to communications and radar systems.

846. Information Theory and Coding
Spring of even-numbered years. 3(3-0)
SYS 863 or approval of instructor.

847. Communication Engineering
Fall. 4(4-0) E E 457. Interdepartmental with Systems Science.

848. Communication Theory
Spring. 3(3-0) SYS 863. Interdepartmental with Systems Science.
Hypothesis testing, decision theory and parameter estimation in communications and signal processing. Optimal filtering techniques. Communication in non-white noise. Quantum detection theory.

849. Microwave Electronics
Spring of odd-numbered years. 3(3-0)
E E 835, E E 875.
Microwave gaseous, solid-state and vacuum devices, active microwave integrated circuits and systems, waves in solid-state plasmas and their applications, parametric amplifiers. Design of microwave amplifiers, oscillators and communication systems.

850. Electrodynamics of Plasmas I
Fall. 3(3-0) E E 835 or PHY 448; E E 874.
Interdepartmental with the Department of Physics and Astronomy.
Boltzmann equation; moment equations; two-fluid theory of plasma, waves in cold, warm and anisotropic infinite plasma; waves in bounded plasma structures. Energy flow in anisotropic plasmas.

857. Microprocessor-based System Design
Spring. 4(2-6) E E 431 or CPS 423.
Microprocessor-based system design methodology; performance measures; single-chip computer organization alternatives; local networks of processors; applications in signal processing control and instrumentation.

863. Analysis of Stochastic Systems
Winter. 3(3-0) SYS 826, STT 441, MTH 424. Interdepartmental with and administered by Systems Science.
Analysis and modeling of stochastic signals and systems. Topics include stochastic models, description of processes, stationarity, ergodicity, correlation and power spectrum, linear stochastic systems, harmonic analysis, Markov processes, Poisson processes.

871. Integrated Circuit Engineering
Winter. 3(3-0) E E 474.
Fabrication and design of integrated circuits. Application of quantum mechanics in solids, band theory of semiconductors, electrical transport phenomena, induced current concept, fundamental current, charged particle dynamics, electron optics.

875. High Speed Solid-State Devices
Winter. 3(3-0) E E 474.
Formulation of operating properties and appropriate models of devices formed with semiconductors and solid state materials. Emphasis is on performance limitations of high speed integrated circuit unipolar and bipolar devices.

876. Semiconductor Power Devices
Spring of even-numbered years. 3(3-0)
E E 474.
Formulation of operating properties and appropriate models of devices formed with semiconductors and solid state materials. Performance limitations of semiconductor power devices due to voltage, temperature and power considerations.

880. Digital Signal Processing
Winter. 3(3-0) E E 456 or STT 441. Interdepartmental with Systems Science.
Discrete time signals and systems, random discrete time signals. Basic principles of estimation theory, spectral estimation. Digital filter design techniques.

899. Master's Thesis Research
Fall, Winter, Spring, Summer. Variable credit. Approval of department.

911. General Automata Theory I
Fall of odd-numbered years. 3(3-0) CPS 423 or SYS 827 or approval of department.
Interdepartmental with and administered by the Department of Computer Science.
Characterization of machines and programs as automata; mathematical decomposition of finite automata.

920. Advanced Topics on Power
Winter. 3(3-0) E E 823 or E E 824.
Current research topics in power system planning, operation and control. Topics may include AC/DC systems, computational methods for balanced and unbalanced systems, stability, and security.

921. Advanced Computer Systems I
Fall. 3(3-0) Two graduate level courses in computer system design (hardware or software). Interdepartmental with and administered by the Department of Computer Science.
Design and characterization of parallel algorithms. Matching algorithms with appropriate hardware configurations. Programming languages which support parallel computation.

926. Antenna Theory I
Winter of even-numbered years. 3(3-0) E E 835.
Wire antennas as radiating, receiving and scattering elements; analytical and numerical integral equation methods; coupled antennas and arrays; transient phenomena.

927. Antenna Theory II
Spring of even-numbered years. 3(3-0) E E 826.
Radiation by equivalent aperture fields; aperture antennas, slot antennas, horn and reflector antennas, frequency independent antennas, pattern theory; scattering from various objects.

929. Advanced Topics in Electromagnetics
Winter. 2 to 4 credits. May reenroll for a maximum of 4 credits. E E 835 and approval of department.
Topics will be drawn from contemporary research areas such as transient electromagnetics (SEM solutions), open boundary waveguides, solid-state lasers, and microwave plasmas.

931. Electronic Properties of Semiconductors
Winter of odd-numbered years. 3(3-0) E E 874.
Advanced treatment of phenomena basic to semiconductor materials and devices. Electronic transport, high field effects, recombination theory, electro-optical phenomena, experimental characterization techniques.
311. Discrete-Time Systems
Fall, Winter, 3(3-0) MTH 215.
Discrete-time system modeling, discrete-time signals, difference equations, convolution summations, z-transform, transfer functions, stability analysis, digital filters.

355. Deterministic Communication Systems
Fall, Spring. 3(3-0) E E 301, MTH 214. Interdepartmental with and administered by Electrical Engineering.
Communication systems. Representation of signals in time and frequency domain. Processing of signals by linear, simple nonlinear and time-invariant systems. Linear and nonlinear, analog and digital modulation and demodulation; for example, AM, FM, PCM.

404. Biological and Ecological Concepts for Engineers and Mathematicians
Winter. 3(3-0) Approval of department, interdepartmental with and administered by the Department of Zoology.
Biological and ecological concepts important to formal analysis of living systems, vital properties, populations, ecosystems, dynamical selection competition, and predation; ecological community structure and function; industrialized ecosystem.

411. Systems Project
Spring. 3(3-0) SYS 410.
Completion of a systems study initiated in SYS 410. The project may involve the design of hardware, simulation of a solution to an interdisciplinary problem, or development of a solution concept.

412. State Models, Analysis, and Simulation
Spring. 3(3-0) SYS 311, MTH 310, MTH 334. Interdepartmental with Electrical Engineering.
Vector-matrix state-space models of dynamic systems, exponential matrix, transform solutions, convolution, stability, controllability, observability, simulation, computational techniques, extensions to nonlinear systems.

413. Analysis of Control Systems
Spring, Fall. 4(4-0) E E 301, E E 335. Interdepartmental with Electrical Engineering.
Control system characteristics, performance criteria, transient and steady-state responses, error analysis, stability, root locus and frequency response techniques. Controller design using root locus and frequency response methods.

414. Control Systems Laboratory
Winter, Spring. 4(4-0) MTH 311, E E 304, SYS 441. Interdepartmental with and administered by Electrical Engineering.
Experimental investigations of feedback systems. Study of solid state controllers. Properties and applications of phase lock loops. Introduction to digital control.

415. Digital Control Systems
Winter. 3(3-0) E E 231, SYS 311, SYS 312. Interdepartmental with and administered by Electrical Engineering.
Organization of digital control systems, classical and modern techniques for the design of digital control systems. Hardware and software considerations with emphasis on microprocessor implementation.

442. Systems Concepts for Biologists
Winter. 3(3-0) Approval of department.
Basic concepts of systems science important to formal analysis and control of biological communities, with emphasis on modeling and on analysis of behavior through numerical solutions.
827. Nonlinear Systems Analysis
Spring, 4(4-0) SYS 826, MTH 424.
Existence, uniqueness and stability in nonlinear systems; autonomous systems and the phase space; linearization, perturbation, describing functions and harmonic balance procedures; numerical solutions.

829. Linear Multivariable Control Systems
Winter, 4(4-0) SYS 826, STT 441, SYS 413.
Linear continuous time and discrete time multivariable control systems; state and output feedback; observers; eigenstructure placement; asymptotic tracking; optimal linear control; stochastic processes; Kalman filter; LQG optimal control.

835. Static Optimization Methods
Summer, 4(4-0) MTH 454. Students may not receive credit for both SYS 855 and MGT 835.
Linear and nonlinear optimization examples and applications; Kuhn-Tucker theory; saddle point optimality conditions; algorithms for problems with constraints; unconstrained optimization; introduction to search methods.

841. Optimization of Urban Traffic Flow
Fall of even-numbered years. 3(3-0) C E 446, STT 363 or approval of department.
Interdepartmental with and administered by Civil Engineering.
Traffic flow models used in design of computerized traffic control systems. Optimal freeway ramp metering algorithms. Offline and online optimization of traffic signal timing.

843. Ecosystem Analysis, Design and Management
Spring, 3(3-0) SYS 442 or ZOL 404. Interdepartmental with the Department of Zoology.
Groups of students from various biological and nonbiological disciplines will synthesize and analyze models of selected biological systems. Project should yield information relevant to solution of contemporary ecological problems.

847. Communication Engineering
Fall, 4(4-0) E E 457. Interdepartmental with and administered by Electrical Engineering.

848. Communication Theory
Spring, 3(3-0) SYS 863. Interdepartmental with and administered by Electrical Engineering.

851. Modeling of Engineering Systems I
Fall, 3(3-0) M E 489 or E E 415. Interdepartmental with and administered by the Department of Mechanical Engineering.
Modeling of components and dynamic systems; mechanical, electrical, fluid, thermal, and transistor effects. Linear space responses; impedance methods. Simulation of linear models. Design project.

852. Modeling of Engineering Systems II
Winter, 3(3-0) M E 851. Interdepartmental with and administered by the Department of Mechanical Engineering.

863. Analysis of Stochastic Systems
Winter, 3(3-0) SYS 826, STT 441, MTH 424. Interdepartmental with Electrical Engineering.
Analysis and modeling of stochastic signals and systems. Topics include stochastic models, description of processes, stationarity, ergodicity, correlation and power spectrum, linear stochastic systems, harmonic analysis, Markov processes, Poisson processes.

889. Digital Signal Processing
Winter, 3(3-0) E E 456 or STT 441. Interdepartmental with and administered by Electrical Engineering.
Discrete time signals and systems, random discrete-time signals. Basic principles of estimation theory, spectral estimation. Digital filter design techniques.

947. Topics in Communications
Fall of odd-numbered years. 3(3-0) May reenroll for a maximum of 6 credits. E E 845. Interdepartmental with and administered by Electrical Engineering.
Advanced treatment of a topic or group of topics of current research interest in the field of communications, information theory and signal processing.

961. Optimal Control Theory
Fall of odd-numbered years. 3(3-0) SYS 829, MTH 424.
Optimal control, performance measures, principle of optimality, dynamic programming, Hamilton-Jacobi Bellman equation, variational approach, constrained extremum, Pontryagin principle, necessary conditions, solution techniques, singular cases.

962. Computational Techniques for Optimal Control
Winter of even-numbered years. 3(3-0) SYS 861.
Computational methods of optimal controls, steepest descent, gradient extremals, normalized, gradient projection, dynamic programming, convexity techniques, support functions for reachable sets, current literature.

963. Dynamic System Identification
Winter of odd-numbered years. 3(3-0) SYS 863.
Review of stochastic system modeling; identifiability; canonical forms; spectral factorization; least squares and maximum likelihood identification methods and their properties, consistent estimators, closed-loop system identification, recursive algorithms; experiment design.

964. Large Scale Dynamic Systems
Spring of even-numbered years. 3(3-0) SYS 827, MTH 829. Topics will be drawn from: model reduction and aggregation; stability of interconnected systems; multiple time scale decomposition; decentralized control; hierarchical control.

985. Adaptive Control
Spring of odd-numbered years. 3(3-0) SYS 827, SYS 829, SYS 983.
Model reference adaptive control in continuous time and discrete time. Lyapunov and positivity approaches; adaptive observers; self tuning regulators; design using pole-zero assignments, minimum variance control and LQG control.

999. Doctoral Dissertation Research
Fall, Winter, Spring, Summer. Variable credit. Approval of department.