877. *Statistical Inference in Economics II*

Winter. 3(3-0) EC 876 or approval of department. Interdepartmental with the departments of Agricultural Economics, and Statistics and Probability.

Specification interpretation and estimation of simultaneous equation models. Nonlinear models. Bayesian approach to estimation problems. Recent developments in econometrics.

878. *Statistical Inference in Economics III*

Spring. 3(3-0) EC 877 or approval of department. Interdepartmental with the departments of Agricultural Economics, and Statistics and Probability.

Validation and application of dynamic econometric models. Bayesian approach to estimation problems. Recent developments in econometric methods and in applied econometric research.

880. *Organization and Control in the Political Economy: Institutions and Theory*

Winter of even-numbered years. 4(4-0) Interdepartmental with the Department of Management.

Organization and technique in choice and implementation of economic (especially planning, programming) functions of political authority.

881. *Organization and Control in the Political Economy: Selected Problems*

Winter of odd-numbered years. 4(4-0) Approval of instructor. Interdepartmental with the Department of Management.

Analysis of role and tasks, appropriate techniques and organizational structures of political agencies in planning and management of complex programs.

891. *Topics in Applied Econometrics*

Spring. 3(3-0) EC 835 or EC 877.

Topics in applied econometrics with particular attention to problems of testing hypotheses in the context of economic models.

895. *Graduate Reading in Economics*

Fall, Winter, Spring, Summer. Variable credit.

900. *Special Topics in Economic Theory*

Fall, Winter, Spring, Summer. 3(3-0) May reenroll for a maximum of 12 credits. EC 812C; EC 813C.

Special topics in economic theory of current interest and importance.

972. *Methodological Approaches to Research*

Fall of even-numbered years, Summer of odd-numbered years. 3(3-0) Two terms of graduate study in social science or approval of department. Interdepartmental with and administered by the Department of Agricultural Economics.

Selection, planning and conduct of research. Alternative research approaches. Role of theory, beliefs and valuations. Critical appraisal of research studies.

990B. *Industrial Organization and Public Policy Workshop*

Fall, Winter, Spring. 3 to 16 credits. Approval of department.

Critical evalution of research reports by staff and other students. Students writing doctoral dissertations in the appropriate areas are encouraged to participate in workshop and may do so while registered for EC 999.

990C. *Mathematical Economics and Econometrics Workshop*

Fall, Winter, Spring. 3 to 16 credits. EC 812A, EC 832; or approval of department. Interdepartmental with the Department of Agricultural Economics.

Critical evaluation of research reports by staff and other students. Students writing doctoral dissertations in the appropriate areas are encouraged to participate in workshop and may do so while registered for EC 999.

990D. *Economic Development Workshop*

Fall, Winter, Spring, Summer. 3 to 16 credits. EC 850, EC 851, EC 852 or approval of department.

Critical evaluation of research reports by staff and students. Students writing doctoral dissertations in Development are encouraged to participate in the workshop and may do so while registered for EC 999.

999. *Doctoral Dissertation Research*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

EDUCATION

See Administration and Curriculum; Counseling, Educational Psychology and Special Education; and Teacher Education.

ELECTRICAL ENGINEERING AND SYSTEMS SCIENCE

College of Engineering

Electrical Engineering — *E E*

230. *Digital Logic Fundamentals*

Fall, Winter, Spring, Summer. 4(4-0) CPS 120 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.

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.

Current voltage and power. DC and transient circuit analysis. Forced response. Sinusoids and the phasor concept. Bridges.

301. *Electric Circuits II*

Winter, Spring. 4(4-0) E E 300, MTH 214.

Sinusoidal steady-state response. Average power and rms concepts. Complex frequency response. Magnetically coupled circuits. Two-port networks. Transfer functions.

302. *Basic Electronic Circuits*

Spring, Summer. 4(4-0) E E 301, MTH 215.

Volt-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 fundamentals. 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.

Experimental verification of topics covered in E E 302. Single-stage and multi-stage transistor amplifier design and analysis. Applications of linear integrated circuits. Computer-aided circuit design.

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, dieletric media, capacitance, and energy storage. Boundary value problems for electronstatic fields.

306. *Electromagnetic Fields and Waves II*

Winter, Spring. 4(4-0) E E 305.

Magnetostatic fields; EM sources, vector potential, magnetic media, inductance, and energy storage, time-varying fields and Maxwell's equations; potential theory and boundary-value problems. Energy conservation and conversion.

307. *Electromagnetic Fields and Waves III*

Spring, Summer. 3(3-0) E E 306; E E 308 concurrently.

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*

Spring, Summer. 1(0-3) E E 306; E E 307 concurrently.

Experimental investigation of: charged particle motion in EM fields, dieletric 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.

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*

(455.) 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 or SYS 312. 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*

(464.) Winter. 1(0-3) E E 231, E E 304, E E 413. Interdepartmental with Systems Science.

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 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 120, 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 uses 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.

420. *Electromechanical Energy Conversion*

Spring. 3(3-0) E E 301, E E 306.

Review of electromagnetics; design, specification, and use of d.c. machines in industrial and servo-control application, synchronous generators and transformers for power systems; three phase power, per unit notation.

421. *Power System Analysis*

Fall. 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.

430. *Digital Electronics I*

Fall, 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. *Digital Electronics II*

Fall, Winter, Summer. 3(2-3) E E 231; 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 307.

Waves guided by open and closed-boundary systems. Normal modes of microstrip, metallic and dielectric waveguides. Microwave cavities, devices, and circuit theory. S-parameter description of microwave devices. System applications.

436. *Radiation and Reception of Electromagnetic Waves*

Winter. 3(3-0) E E 307.

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 aperture antennas.

438. *Transmission and Radiation Laboratory*

Winter. 1(0-3) 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.

Probability theory applied to communications. Representation of random signals as stochastic processes. Autocorrelation and spectral density. Noise in components and systems, performance of analog linear and nonlinear systems with noise.

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. Communication systems such as radar, television, PCM, and telephony.

467. *Communications Laboratory*

Spring. 1(0-3) 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 BJT.

475. *Electronic Devices and Circuits*

Winter. 3(3-0) E E 474.

Fabrication technology; models and characteristics of BJT's, JFET's, 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, diacs, triacs, and SCR's; high frequency devices and applications; transitors; impatt, Gunn and vacuum devices; photo-devices; solar cells and LED's.

477. *Electro-optic Devices*

Spring of odd-numbered years. 3(3-0) E E 306.

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 economic considerations.

480. *Integrated Circuits: Operational Amplifiers*

Fall, Winter. 3(3-0) E E 302.

Integrated circuits: design principles and fabrication. Differential-amplifier stage signal characteristics. Properties and models of operational amplifiers. Applications: signal conditioners, signal processors, signal generators, and special-purpose circuits.

484. *Electronic Devices Laboratory*

Winter. 1(0-3) E E 474.

Measurement of semiconductor bulk properties; device fabrication; experimental study of selected electron devices and design application based on principles discussed in E E 474.

490. *Special Topics in Electrical Engineering*

Fall, Winter, Spring, Summer. 1 to 4 credits. May reenroll for a maximum of 12 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 SYS 495 combined. Approval of department.

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 499 and SYS 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 systems.

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 431 or CPS 423. Interdepartmental with the Department of Computer Science.

Number systems; fast two-operand and multioperand addition/subtraction; standard, recoded and cellular array multipliers; high-performance dividers; floating-point arithmetic; error control; pipelining.

811. *Noise and Fluctuation Phenomena*

Spring of even-numbered years; Summer of odd-numbered years. 3(3-0) Approval of department.

Nyquist formulation of thermal noise; noise phenomena associated with electron tubes, transistors, beam and parametric devices, amplifiers, mixers, and detectors; techniques and equipment for noise measurements.

813. *Logic Design Methodologies*

Spring. 3(3-0) CPS 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*

Winter. 3(3-0) CPS 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 M 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.

822. *Analysis of Faulted Power Systems*

Winter. 4(4-0) SYS 826.

Symmetrical components; models of generators, transformers, transmission lines; calculation of short circuits for symmetrical and unsymmetrical faults; system protection devices and practice.

823. *Power System Stability and Control*

Fall of even-numbered years. 3(3-0) SYS 826.

Analysis and simulation of small and large disturbance stability of power systems; generator, exciter, voltage regulator models; design of excitation systems and power system stabilizers.

826. *Advanced Linear Systems Analysis*

Fall. 4(4-0) MTH 310, MTH 334. Interdepartmental with and administered by Systems Science.

Unified analysis of linear continuous-time and discrete-time systems for both time-invariant and time-varying models; mathematical descriptions, transforms, state models; transition matrices; solution techniques; controllability; observability; stability.

831. *Active Network Synthesis*

Winter. 3(3-0) Approval of department.

S-domain network synthesis. Root-locus design techniques for practical analog signal processors, including sensitivity and stability considerations. Passive network synthesis and functional properties of operational amplifiers.

835. *Electromagnetic Theory*

Fall. 3(3-0) Approval of department.

Electrostatics, magnetostatics, electrodynamics and Maxwell's equations. Green's function and eigenfunction expansion techniques. Conservation of EM energy and momentum. Radiation of EM waves: Lorentz potentials, Helmholtz integrals, retarded potentials, general EM field.

836. *Electromagnetic Waves I*

Winter. 3(3-0) E E 835.

EM description of circuits. EM boundary-value problems. Hertzian potentials. Field equivalence theorems. Green's functions. TEM waves: propagation in curvilinear coordinates, transmission and scattering coefficients. Transmission lines: variational methods, microstrip.

837. *Electromagnetic Waves II*

Spring. 3(3-0) E E 836.

Guided transmission systems. Modes of metallic and open-boundary dielectric waveguides and cavities. Mode orthogonality. Excitation and coupling. Scattering by waveguide discontinuities. Radiation modes. Fiber and integrated optics.

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, EM optics and scalar diffraction; lenses; optical imaging systems; optical information processing; holography.

847. *Communication Engineering*

Fall. 4(4-0) E E 456 or approval of instructor. Interdepartmental with Systems Science.

Communications in probabilistic channels. Measures in system performance. Channel models. Optimal reception of analog and digital signals. Coding for various channel models. Detection of targets. Signal solution.

848. *Communication Theory*

Spring. 3(3-0) E E 847, E E 880, E E 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. Communication in non-Gaussian 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) E E 415, E E 456. 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. Physics and chemistry of processing. Comparison of current bipolar and MOS technologies, and their limitations. VLSI design methodology and layout examples.

874. *Physical Electronics*

Fall. 4(4-0) Approval of department.

Application of quantum mechanics in solids, band theory of semi-conductors, electrical transport phenomena, induced current concept, 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. *Signal Analysis*

Winter. 3(3-0) Approval of department. Interdepartmental with Systems Science.

Continuous and discrete signals—generation, representation and classification. Fourier transform, spectral analysis and filtering for continuous and discrete signals. Computer implementation of signal processing.

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.

912. *General Automata Theory II*

Winter of even-numbered years. 3(3-0) CPS 911. Interdepartmental with and administered by the Department of Computer Science.

Reliability and redundancy of finite automata. Probabilistic sequential machines. Languages definable by probabilistic and deterministic automata. Axioms for equivalence of regular expressions.

913. *General Automata Theory III*

Spring of even-numbered years. 3(3-0) CPS 912. Interdepartmental with and administered by the Department of Computer Science.

Degrees of difficulty of computation. Models of parallel computation. Iterative automata.

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 Deparment of Computer Science.

Models of single and multiple processors, their computational power, and measures of performance. Interconnection networks, data driven machines, and pipelines.

922. *Advanced Computer Systems II*

Winter. 3(3-0) CPS 921. Interdepartmental with and administered by the Department of Computer Science.

Design and characterization of parallel algorithms. Matching of 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 926.

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*

Fall, Winter, Spring, Summer. 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.

932. *Topics in Solid State Device Research*

(930.) Spring of odd-numbered years. 3(3-0) E E 874.

Relationship of solid state theory and material properties to device performance. Topics selected from current device research areas and vary with year. Examples are photovoltaic, amorphous semiconductor, and piezoelectric devices.

947. *Topics in Communications*

Fall of odd-numbered years. 3(3-0) May reenroll for a maximum of 6 credits. E E 848. Interdepartmental with Systems Science.

Advanced treatment of a topic or group of topics of current research interest in the field of communications, information theory and signal processing.

975. *Quantum Electromagnetics*

Winter of odd-numbered years. 3(3-0) E E 874.

Emission, absorption and amplification of radiation; energy levels for optically active materials; kinetic modeling of plasmas and chemically reacting plasmas; rate equation modeling and empty cavity modes of lasers and masers.

976. *Lasers and Masers*

Spring of odd-numbered years. 3(3-0) E E 975.

Advanced modeling of lasers and masers, quantization of wave fields, line width, multimode phenomena, mode locking, ring and Zeeman lasers, recent developments and applications.

989. *Electrodynamics of Plasmas II*

Winter of odd-numbered years. 3(3-0) E E 850. Interdepartmental with the Department of Physics and Astronomy.

One fluid plasma model, magnetohydrodynamics, Maxwell's stress tensor, low frequency waves, transport phenomena, Landau damping, collision and rate coefficients. Diffusions in a magnetic field; investigation of dc, rf and microwave discharges.

999. *Doctoral Dissertation Research*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

Systems Science SYS

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*

(455.) 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-variant 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, processes, and limitations; population dynamics, selection competition, and predation; ecological community structure and function; industrialized ecosystem.

410. *Systems Methodology*

Winter. 3(3-0) MTH 113, CPS 110 or CPS 120.

The systems approach in multidisciplinary large scale problem solving. The development of useful systems analysis tools; systems design; feasibility study; computer simulation for feasibility evaluation.

411. *Systems Project*

Spring. 2(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*

(313.) Fall. 4(4-0) E E 301, E E 355 or SYS 312. 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*

(464.) Winter. 1(0-3) E E 231, E E 304, E E 413. 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 413. 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.

465. *Process Optimization Methods*

Fall. 3(3-0) MTH 310. Interdepartmental with and administered by the Department of Chemical Engineering.

Methods for determining optimum design and operating policies of systems of varying complexity. Includes classical methods, mathematical programming and modern methods.

495. *Independent Study*

Fall, Winter, Spring, Summer. 1 to 3 credits. May reenroll for a maximum of 3 credits in SYS 495 and E E 495 combined. Approval of department.

Independent study of a topic in systems science 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 SYS 499 and E E 499 combined. Approval of department.

Independent undergraduate research in contemporary areas of systems science.

801. *Special Problems*

Fall, Winter, Spring, Summer. 1 to 4 credits. May reenroll for a maximum of 8 credits. Approval of department.

810. *Introduction to Linear System Theory*

Fall. 3(3-0) MTH 214. May not be used for graduate credit by College of Engineering majors except Operations Research/Systems Science. Interdepartmental with the College of Social Science.

A first course in system theory for students from a range of disciplines. Mathematical representation of system variables, transform and state space method of analysis, introduction to control theory, applications to physical, economic and social systems.

811. *System Methodology and Simulation*

Winter. 3(3-0) SYS 810, STT 441. Interdepartmental with the College of Social Science.

Problem definition, design of abstract models for system design and control, simulation of systems described by differential and difference equations, generation of random variables, simulation of discrete object stochastic systems, simulation languages, applications to physical, economic and social systems.

813. *System Project*

Spring. 3(1-6) SYS 811. Interdepartmental with the College of Social Science.

Individual or team application of simulation methods to system design and/or management.

814. *Advanced System Methodology and Simulation*

Spring. 3(3-0) SYS 811.

Simulation of a class of time-varying distributed parameter processes; organization and design of large simulation models; optimization and parameter estimation in large simulation models; applications to economic, social and biological systems; other topics of current interest.

826. *Advanced Linear Systems Analysis*

Fall. 4(4-0) MTH 310, MTH 334. Interdepartmental with Electrical Engineering.

Unified analysis of linear continuous-time and discrete-time systems for both time-invariant and time-varying models; mathematical descriptions, transforms, state models; transition matrices; solution techniques; controllability; observability; stability.

827. *Nonlinear Concepts in Systems Science*

Winter. 4(4-0) SYS 826.

Existence, uniqueness and stability in nonlinear systems; autonomous systems and the phase space; linearization, perturbation, describing functions and harmonic balance procedures; numerical solutions.

829. *Modern Control Systems*

Spring. 4(4-0) STT 441, SYS 826.

Stochastic processes and white noise; analysis of linear continuous-time control systems; state feedback design; state observer design; optimal linear control and Kalman filter; linear discrete-time control systems.

835. *Nonlinear Optimization Models*

Summer. 4(4-0) MTH 215; MGT 834 or CHE 465. Students may not receive credit for both SYS 835 and MGT 835.

Nonlinear optimization-examples and applications. Kuhn-Tucker Theory. Saddle point optimality conditions. Algorithms for problems with constraints. Unconstrained optimization; introduction to search methods.

838. *Feasibility Analysis of Energy Systems*

Spring. 3(3-0) STT 441.

Methods for selecting energy conversion and transmission facilities with emphasis on electric utilities. Demand forecasting system reliability; selection of size, type and location of conversion facilities; cost analysis.

841. *Optimization of Urban Traffic Flow*

Fall of odd-numbered years. 3(3-0) Approval of department. Interdepartmental with 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 456 or approval of instructor. Interdepartmental with and administered by Electrical Engineering.

Communications in probabilistic channels. Measures in system performance. Channel models. Optimal reception of analog and digital signals. Coding for various channel models. Detection of targets. Signal solution.

848. *Communication Theory*

Spring. 3(3-0) E E 847, E E 880, E E 863. Interdepartmental with and administered by Electrical Engineering.

Hypothesis testing, decision theory and parameter estimation in communications and signal processing. Optimal filtering techniques. Communication in non-white noise. Communication in non-Gaussian noise. Quantum detection theory.

851. *Modeling of Engineering Systems I*

Fall. 3(3-0) M E 458 or E E 415. Interdepartmental with and administered by the Department of Mechanical Engineering.

Modeling of engineering components and dynamic systems; mechanical, electrical, fluid, thermal, and transducer effects. Linear state-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.

Continuation of M E 851. Modeling of nonlinear dynamic systems. Applications of phase-plane and linearization methods. Simulation of nonlinear systems. Design project.

863. *Analysis of Stochastic Systems*

Winter. 3(3-0) E E 415, E E 456. 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.

880. *Signal Analysis*

Winter. 3(3-0) Approval of department. Interdepartmental with and administered by Electrical Engineering.

Continuous and discrete signals—generation, representation and classification. Fourier transform, spectral analysis and filtering for continuous and discrete signals. Computer implementation of signal processing.

899. *Master's Thesis Research*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

947. *Topics in Communications*

Fall of odd-numbered years. 3(3-0) May reenroll for a maximum of 6 credits. E E 848. 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. 3(3-0) SYS 827, MTH 426.

Optimal control, performance measures, principle of optimality, dynamic programming, Hamilton-Jacobi-Bellman equation, variational approach, constrained extrema, Pontryagin principle, necessary conditions, solution techniques, singular cases.

962. *Computational Techniques for Optimal Control*

Winter of odd-numbered years. 3(3-0) SYS 961.

Computational methods of optimal controls, steepest descent, variation of extremals, quasilinearization, gradient projection, dynamic programming, convexity techniques, support functions for reachable sets, current literature.

963. *Dynamic System Identification and Control*

Spring of odd-numbered years. 3(3-0) SYS 863, SYS 829.

System identification; dynamic programming; stochastic and adaptive control. Topics under identification include review of statistics background, dynamic system models, identification methods, recursive algorithms, input design, and structure discrimination.

964. *Large Scale Dynamic Systems*

Winter of even-numbered years. 3(3-0) SYS 961.

Model simplification; stability of large scale systems; decentralized control; optimization by decomposition and coordination; multilevel hierarchical control; applications.

999. *Doctoral Dissertation Research*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

ENGINEERING EGR

College of Engineering

1255. *Orientation to Engineering Careers*

Winter. 2(2-0) Credits earned in this course are included in computation of GPA and MAPS but are not included in the 180 credits required for graduation.

Engineering careers, history and philosophy of engineering profession, present and future challenges, industrial job functions, employment trends.

200. *Technology, Society and Public Policy*

Winter. 3(3-0) Twelve credits from natural science or engineering. Interdepartmental with the Department of Natural Science.

Description and analysis of certain current technologies and their consequences; exploration of avenues for assessing such consequences as an aid to formulation of public policy.

290. *Selected Topics*

Fall, Winter, Spring, Summer. 1 to 3 credits May reenroll for a maximum of 6 credits if different topics are taken.

Experimental course developments or special topics appropriate for freshmen and sophomores.

344. *Engineering Cooperative Education*

Fall, Winter, Spring, Summer. Zero credits. [3 credits-See page A-1, item 3.] May reenroll for a maximum of six terms. Employment assignment approved by College of Engineering.

Pre-professional employment in industry and government related to student's major.

390. *Value Engineering*

Fall, Winter, Spring. 4(4-0) MMM 280 or approval of department.

The basis of value engineering is function, value, and a group of special techniques developed to aid in isolating and identifying problems created by our complex society and technology.

401. *Engineering and Public Policy*

Spring. 3(3-0) Seniors or approval of department. Interdepartmental with the Department of Natural Science.

Sociotechnical assessment of impact of technology on society, with analysis of the role of engineering and natural science in contributing to public policy formulation.

ENGLISH ENG

College of Arts and Letters

091. *English for Foreign Students–Structures*

Fall, Winter, Spring, Summer. Zero credits. [3(5-0) See page A-1 item 3.] English language proficiency examination.

Explanation and intensive practice of basic grammatical structures of English. Students are tested and then placed in small groups, from beginning to advanced, depending on their need.

092. *English for Foreign Students–Speaking and Listening*

Fall, Winter, Spring, Summer. Zero credits. [3(5-0) See page A-1 item 3.] English language proficiency examination.

Intensive speaking and listening practice of spoken English in small groups (determined by proficiency). For beginners, practice is largely drill. Advanced groups use drill, films, discussion, and practical conversations.

093. *English for Foreign Students–Language Laboratory*

Fall, Winter, Spring, Summer. Zero credits. [3(5-0) See page A-1 item 3.] English language proficiency examination.

Language laboratory practice in small groups (determined by proficiency). Beginnings review and supplement ENG 091, ENG 092. Advanced groups use carefully prepared lectures, speeches, and presentations to practice structures and vocabulary.

094. *English for Foreign Students–Reading*

Fall, Winter, Spring, Summer. Zero credits. [3(5-0) See page A-1 item 3.] English language proficiency examination.

Intensive and extensive reading in small groups (determined by proficiency). Beginners emphasize vocabulary development and practice in basic structures. Advanced classes include reading skills, wider reading, and specialized vocabulary.

095. *English for Foreign Students–Writing*

Fall, Winter, Spring, Summer. Zero credits. [3(5-0) See page A-1 item 3.] English language proficiency examination.

Frequent controlled and free writing in small groups to reduce errors and practice using structures and vocabulary to express ideas. Advanced classes include writing styles used in academic course work.

101. *Responses Through Writing*

Fall. 4(4-0) Arts and Letters Freshmen only. Students must enroll in and complete ENG 102 satisfactorily to make a substitution for the American Thought and Language requirement.

A writing workshop that concentrates on the students' personal writing voice and on their responses to the things, people, and institutions central to their experience.

102. *Writing and Composing*

Winter. 5(5-0) ENG 101; Arts and Letters Freshmen only.

A continuation of ENG 101 that develops the emphases of ENG 101 and encourages students to write in more public and objective forms—narrative, critical analysis, and issue-oriented essays.

104. *Writing for Science Majors*

Fall. 3(3-0) Satisfactory grade in English proficiency exam; College of Natural Science majors. Interdepartmental with the Department of American Thought and Language.

Writing workshop for science students that develops and refines composition ability.

105. *The Scientist as Writer*

Winter. 3(3-0) ENG 104. Interdepartmental with the Department of American Thought and Language.

Study of various types of writing by scientists—fiction, poetry, and autobiography as well as professional papers and books. Students will write frequently about the readings.

106. *Introductory Scientific Writing*

Spring. 3(3-0) ENG 105. Interdepartmental with the Department of American Thought and Language.

Writing of popular essays, scientific papers and reports, and other papers related to science.

126. *The Writer and Literature*

Fall, Winter, Spring. 3(3-0) The first term of ATL 121 or above or ENG 101.

Modern literature from the writer's perspective. Students also write their own critical and creative work, using journal method.

200H. *Honors Work*

Fall, Winter, Spring. 1 to 16 credits. Approval of department.

201. *Nature of Language*

Fall, Winter, Spring, Summer. 3(3-0)

Various aspects of language—phonology and orthography; morphology, semantics and the lexicon; syntax; and dialects—with special reference to American English.

205. *Introduction to Shakespeare*

Fall, Winter, Spring. 3(3-0) Not applicable to major or minor requirements.

A study of selected plays illustrating the powers of England's greatest writer.

206. *Forms of Literature: Fiction*

Fall, Winter, Spring, Summer. 3(3-0) Open to Freshmen.

Major forms of prose fiction, designed to reveal artistic problems met and solved by these forms. Prepares students for advanced literary study by acquainting them with the conventions of various literary forms, by providing a critical vocabulary and by furnishing experience in reading and writing critical evaluations of outstanding literary works from all historical periods.

207. *Forms of Literature: Drama*

Fall, Winter, Spring, Summer. 3(3-0) Open to Freshmen.

Major forms of drama, designed to reveal artistic problems met and solved by these forms.

208. *Forms of Literature: Poetry*

Fall, Winter, Spring, Summer. 3(3-0) Open to Freshmen.

Major forms of poetry, designed to reveal artistic problems met and solved by these forms.

210. *Introduction to the Study of Literature I*

Fall, Winter. 4(4-0) English majors or prospective English majors.

Exploration of the major forms of literature, the aims and process of literary study, the cultural and personal functions of literature, and the role of literary study in the University.