College of Engineering

Engineering programs offered at Cornell lead to the degrees of Bachelor of Science, Master of Engineering, Master of Science, and Doctor of Philosophy. Descriptions of courses, including both undergraduate and graduate offerings, are given under the appropriate academic areas.

Information about academic programs, admissions and financial aid, and special opportunities for engineering students is given in other publications of the Announcement series: *Academic Information, General Information, Engineering at Cornell* (for prospective undergraduates), the *Announcement of the Graduate School*, and *Graduate Study in Engineering and Applied Science*.

Division of Basic Studies

The courses available through the Division of Basic Studies include certain engineering courses offered by the various schools and departments of the College of Engineering primarily for underclass students; these courses are described below. Additional engineering courses that may be taken during the freshman and sophomore years in the Division of Basic Studies are described under the appropriate subject areas. Courses in mathematics, physics, and chemistry are described under the appropriate departments of the College of Arts and Sciences

Engineering Basic Studies

DBS 105 Introduction to Computer Programming Fall or spring. 3 credits. DBS 105 is the same as the mathematical section of Computer Science 100.
2 lecs, 1 rec (optional); evening tests.
An introduction to elementary computer programming concepts. Emphasis is on techniques of problem analysis, algorithm and program development. The subject of the course is programming, not a particular programming language. The principal programming language is PL/I; FORTRAN is also introduced and is used for final problems. The course does not presume any previous programming experience. An introduction to numerical computing is included, although no college-level mathematics is presumed. Programming assignments are tested and run on interactive, stand-alone microcomputers.

DBS 106 Engineering Perspectives Fall or spring. 3 credits.
Weekly lecture series for 1 credit plus a supplemental course program for 2 credits. For the course program, each student chooses either (1) two sequential short courses, called minicourses, for 1 credit each, or (2) a 2-credit full-semester engineering course, or (3) a 2-credit full-semester research option under which freshmen work closely with faculty members in ongoing research projects.

Engineering Core Sciences

Group I

OR&IE 213 Systems Analysis and Design Fall. 3 credits. Prerequisite: first-year calculus.
2 lecs, 1 rec.
A general introduction to the problems and techniques of systems engineering and operations research. Includes formation and solutions of problems that can be modeled as networks (shortest path, project scheduling, maximum flow), dynamic programs (inventory and distribution), linear resource allocation problems, and games (conflict resolution and voting). Effects of uncertainty on decision making.

OR&IE 260 Introductory Engineering Probability Fall or spring. 3 credits. Prerequisite: first-year calculus.
3 lecs.
The basic tools of probability and their use in engineering. 260 may be the last course in probability for some students, or it may be followed by OR&IE 361, Stochastic Processes I, or by OR&IE 370, Statistics. Definition of probability; random variables; probability distributions, density functions, expected values; jointly distributed random variables; distribution such as the binomial, Poisson, and exponential that are important in engineering, and how they arise in practice; limit theorems.

OR&IE 270 Basic Engineering Statistics Fall or spring. 3 credits. Students who intend to enter the upperclass Field Program in Operations Research and Industrial Engineering should take OR&IE 260 instead of this course. Prerequisite: first-year calculus.
2 lecs, 1 rec.
At the end of this course a student should command a working knowledge of basic statistics as it applies to engineering work. For many students this will be the only course in statistics. For students who wish to learn more about statistics, a course in probability (OR&IE 260) followed by a course in statistics (OR&IE 370) is recommended.

Com S 211 Computers and Programming Fall or spring. 3 credits. Prerequisite: Computer Science 100 or equivalent programming experience.
2 lecs, 1 lab; 2 evening quizzes.
Intermediate programming in PL/I: procedures, block structures, on conditions, recursion. Introduction to basic data structures and program analysis and simulation, Programming assignments for a variety of applications.

Com S 321 Numerical Methods Fall or spring. 4 credits. Prerequisites: Mathematics 293 or 221 and knowledge of FORTRAN equivalent to what is taught in Com S 100.
3 lecs.
Students solve representative problems by programming appropriate algorithms and using library programs. Numerical methods for systems of linear equations, interpolation, integration, ordinary differential equations, nonlinear equations, optimization and linear least squares.

Group II

Ele E 210 Introduction to Electrical Systems Fall or spring. 3 credits. Prerequisites: Mathematics 192 and Physics 112.
3 lec-rec.
Circuit elements and laws, natural response of linear systems; impedance and pole-zero concepts; complex frequency and phasors; forced response and power systems; transfer function and frequency response; low-frequency terminal characteristics of diodes, triodes, and transistors; linear models of electronic devices; bias circuits and frequency response of amplifiers; operational amplifiers, feedback, and oscillators.

Ele E 230 Introduction to Digital Systems Fall or spring. 3 credits.
2 lecs, 5 lab experiments.
Introduction to basic analysis and design techniques and methodology of digital and computer systems. Boolean algebra; integrated circuit components used in digital system implementation; codes and number systems; logic design of combinational circuits; logic design of sequential circuits.

MS&E 261 Introduction to Electrical Properties of Materials Spring. 3 credits.
2 lecs, 1 rec or lab.
Electronic structure of atoms, molecules, and crystalline solids. Electrical conductivity and other electrical properties of metals, semiconductors, and insulators. Semiconductors and their applications in electronic devices. Magnetism and magnetic materials. Introduction to lasers.

A&EP 206 The Physics of Life Fall. 3 credits. Prerequisite: concurrent registration in Physics 213 or permission of instructor.
3 lecs. W. Webb.
An in-depth study of four biological topics from a physical point of view. Topics covered are photosynthetic conversion of light into chemical energy, proteins as transport and production machines, membranes, and biophysical aspects of replication. Topics are chosen to illustrate the unity and interdependence of living matter.

A&EP 217 Contemporary Topics in Applied Physics Spring. 3 credits. Prerequisite: Physics 213.
2 lecs, 1 rec-lab. R. A. Buhrman.
An introduction to selected applications of modern physics to advanced technology. This course deals with both present and potential approaches to large-scale energy conversion. In particular, the basic physical principles and fundamental limitations of nuclear energy (in terms of both fission and fusion) and of solar energy utilization are presented. One objective of the course will be to give a current view of the present status and future directions of research and development in energy-related fields.

Group III

T&AM202 Mechanics of Solids Fall or spring. 3 credits. Prerequisite: coregistration in Mathematics 293.
2 lecs, 1 rec, 4 labs each semester; evening exams.
Principles of statics, force systems, and equilibrium. Frameworks. Mechanics of deformable solids, stress, strain, statically indeterminate problems. Mechanical properties of engineering materials. Axial force, shearing force, bending moment, singularity functions. Plane stress. Mohr's circle. Bending and torsion of bars; buckling and plastic behavior.

T&AM 203 Dynamics Fall or spring. 3 credits. Prerequisite: coregistration in Mathematics 294.
2 lecs, 1 rec, 4 labs each semester; evening exams.
Newtonian dynamics of a particle, systems of particles, and a rigid body. Kinematics, motion relative to a moving frame. Impulse, momentum, angular momentum, energy. Rigid body kinematics, angular velocity, moment of momentum and the inertia tensor. Euler equations, the gyroscope.

MS&E 261 Introduction to Mechanical Properties of Materials Fall or spring. 3 credits
2 lecs, 1 rec or lab.
The relation of mechanical properties to microscopic structures and defects inside metals and other materials. Deformation or rubber-like polymers. Permanent changes in the shape of crystals caused by the action of stresses. Effect of movement of atoms on the strength of solids at high temperatures. Manipulation of microscopic structure for high strength. Fracture and fatigue failure.

Group IV

Chem 287, 289 Introductory Physical Chemistry and Laboratory Fall. 5 credits. Prerequisites: Chemistry 208 or 216 and Mathematics 191–192.
2 or 3 lecs, 1 rec in 287; 2 labs in 289.
A systematic treatment of the fundamental principles of physical chemistry. Essential experimental skills are developed.

Chem 288, 290 Introductory Physical Chemistry and Laboratory Spring. 5 credits. Prerequisite: Chemistry 287 and 289.
288: 2 or 3 lecs, 1 rec. 290: 1 lec, 2 labs.
A continuation of Chemistry 287, 289.

Chem 357* Introductory Organic Chemistry Fall. 3 credits. Prerequisite: Chemistry 208 or 216.
3 lecs, optional rec may be offered.
A systematic study of the more important classes of carbon compounds: reactions of their functional groups, methods of synthesis, relations, and uses.

Chem 358* Introductory Organic Chemistry Spring. 3 credits. Prerequisite: Chemistry 357.
3 lecs, optional rec may be offered.
A continuation of Chemistry 357.

M&AE 221 Thermodynamics Fall or spring. 3 credits. Prerequisites: Mathematics 191–192 and Physics 112.
3 recs.
The definitions, concepts, and laws of thermodynamics. Applications to ideal and real gases, multiphase pure substances, gaseous mixtures, and gaseous reactions. Heat-engine and heat-pump cycles. An introduction to statistical thermodynamics.

Chem E 111 or 110 Mass and Energy Balances 111, fall; 110, summer. 3 credits. Prerequisites: one year of freshman chemistry. 111 is recommended for students planning to enter the Field Program in Chemical Engineering.
R. G. Thorpe.
Engineering problems involving material and energy balances. Batch and continuous reactive systems in the steady and unsteady states. Humidification processes. Chemical Engineering 110 differs from 111 in that it uses *only self-paced audiovisual instruction at the convenience of the student.* A minimum of 70 clock hours of audiovisual instruction is required to master the subject matter. Student performance in 110 is evaluated by nine tests, two preliminary examinations, and a final examination; superior students may earn exemption from the final examination.

Applied and Engineering Physics

206 The Physics of Life Fall. 3 credits.
Prerequisite: concurrent registration in Physics 213 or permission of instructor.
3 lecs. A. Lewis.
See description under Division of Basic Studies.

217 Contemporary Topics in Applied Physics Spring. 3 credits. Prerequisite: Physics 213.
2 lecs, 1 rec-lab. R. A. Buhrman.
See description under Division of Basic Studies.

303 Introduction to Nuclear Science and Engineering I Fall. 3 credits. Prerequisite: Physics 214 or Mathematics 294. This course and A&EP 304 form a coordinated two-term sequence designed for juniors or seniors from any engineering field who want to prepare for graduate-level nuclear science and engineering courses at Cornell or elsewhere. The sequence can also serve as a terminal introduction to the field. 303 is a reasonably self-contained unit that can be taken by itself by those desiring only one term.
3 lecs. D. D. Clark.
Introductory overview of atomic and nuclear physics, nuclear structure, radioactivity, nuclear reactions, interaction of radiation with matter; reactor physics: neutron moderation, neutron diffusion, the steady-state chain reaction, reactor kinetics. At the level of *Introduction to Nuclear Engineering* by Lamarsh.

304 Introduction to Nuclear Science and Engineering II Spring. 3 credits. Prerequisite: A&EP 303.
3 lecs. D. A. Hammer.
Reactor engineering: heterogeneous reactors, dynamic behavior and control, heat transfer; overview of controlled fusion: fuel cycles, reactor configurations, engineering problems; radiation: biological effects, shielding, radiation protection, damage and materials problems; reactor safety, licensing, and siting.

333 Mechanics of Particles and Solid Bodies Fall. 4 credits.
3 lecs, 1 rec. B. Kusse.
Newton's laws; coordinate transformations; generalized coordinates and momenta. Lagrangian and Hamiltonian formulation; applications to oscillator, restrained motion, central forces, small vibrations of multiparticle systems, motion of rigid body.

355 Intermediate Electromagnetism Fall. 4 credits. Prerequisites: Physics 214 and 216 and coregistration in Mathematics 421 or T&AM 610, or permission of instructor.
D. Hammer.
Topics: vector calculus; electrostatics, magnetostatics, and introduction phenomena; Laplace's equation solutions in Cartesian, cylindrical, and spherical systems; dielectrics, paramagnetic and diamagnetic materials, electric and magnetic forces, energy storage, skin effect, quasistatics. Emphasis on physical concepts and applications.

356 Intermediate Electrodynamics Spring. 4 credits. Prerequisites: A&EP 355, coregistration in Mathematics 422 or T&AM 611, or permission of instructor.
R.V. Lovelace.
Development of electromagnetic wave phenomena and radiation. Topics include transmission lines, waveguides, wave properties of dispersive media, radiation and scattering phenomena, reciprocity, physical optics, and special relativity.

361 Introductory Quantum Mechanics Spring. 4 credits. Prerequisites: A&EP 333 or Physics 318; coregistration in Mathematics 422 or T&AM 611 and in A&EP 356 or Physics 326.
3 lecs, 1 rec. V. Kostroun.
A first course in the systematic theory of quantum phenomena. Topics include the square well, harmonic oscillator, hydrogen atom, and perturbation theory. At the level of Chapters 4–9 of *Modern Physics and Quantum Mechanics* by Anderson.

363 Electronic Circuits (also Physics 360) Fall or spring. 4 credits. Prerequisite: Physics 208 or 213 or permission of instructor; no previous experience with electronics is assumed.
1 sec, 2 labs. Spring, A. Kuckes.
This laboratory course focuses on designing, building, and testing analog, digital, and microprocessor-based circuits that are useful in electronic instrumentation. Analog topics treated include basic circuit concepts, applications of operational amplifiers in linear circuits, oscillators and comparators, transistor circuits, and diodes in power supplies, waveform shaping circuits, and protective circuits. Students also build digital circuits that incorporate Schmidt triggers, comparators, combinatorial and sequential logic using medium-scale integrated circuits. The above circuits are also interfaced to a microprocessor whose architecture, machine instruction set, and programming principles are studied. At level of *Principles of Electronic Instrumentation* by Diefenderfer.

401 Physics of Atomic and Molecular Processes Fall. 3 credits. Prerequisite: A&EP 361, Physics 443, or permission of instructor.
T. A. Cool
An introduction to the basics of contemporary problems in the physics of atomic and molecular processes, including atomic structure, chemical bonding, polarization, radiation resonance processes, and atomic and molecular spectroscopy.

423 Statistical Thermodynamics Spring. 4 credits. For engineering physics seniors; others by permission of instructor.
3 lecs, 1 rec. M. Nelkin.
Quantum statistical basis for equilibrium thermodynamics, canonical and grand canonical ensembles, and partition functions. Quantum and classical ideal gases and paramagnetic systems. Fermi-Dirac, Bose-Einstein, and Maxwell-Boltzmann statistics. Introduction to systems of interacting particles. At the level of *Thermal Physics* by Kittel and *Statistical and Thermal Physics* by Reif.

434 Continuum Physics Fall. 4 credits. Prerequisite: A&EP 333 or equivalent.
R. V. Lovelace.
Linear elasticity theory; tensor and vector formalisms; elementary engineering applications, crystal anisotropy, dislocations. Elastic and inelastic waves. Hydrodynamics; Navier-Stokes equations, ideal and viscous fluids, compressible and incompressible flows; elementary applications, lift, drag, convention, surface waves, simple shocks, sound, introduction to linear response theory, dimensional analysis, instabilities and turbulence, subcritical and supercritical flows.

490 Informal Study in Engineering Physics Credit to be arranged.
Laboratory or theoretical work in any branch of engineering physics under the direction of a member of the staff.

[601 Photosynthesis (also Biological Sciences 445) Fall. 3 credits. Prerequisites: Chemistry 104 or 208, Mathematics 106 or 111, and Physics 102 or 208, or permission of instructor. Offered alternate years. Not offered 1980–81.
R. K. Clayton.
A detailed study of the process by which plants use light in order to grow, emphasizing physical and physiochemical aspects.]

606 Introduction to Plasma Physics (also Electrical Engineering 681) Fall. 3 credits. Prerequisites: A&EP 355, 356, or equivalent. Open to fourth-year students at discretion of instructor.
3 lecs. R. N. Sudan.
Plasma state; motion of charged particles in fields; collisions, coulomb scattering; transport coefficients, ambipolar diffusion, plasma oscillations and waves; bydromagnetic equations; hydromagnetic stability and microscopic instabilities; test particle in a plasma; elementary applications.

607 Advanced Plasma Physics (also Electrical Engineering 682) Spring. 3 credits. Prerequisite: A&EP 606.
3 lecs. R. N. Sudan.
Boltzmann and Vlasov equations; Chew-Goldberger-Low theory; waves in hot plasmas; Landau damping. Micro-instabilities; effects of collisions and Fokker-Planck terms; method of dressed test particles; high-frequency conductivity and fluctuations; neoclassical toroidal diffusion, relativistic beams.

[608 Plasma Astrophysics (also Astronomy 660) Spring. 2 credits. Not offered 1980–81.
R. V. Lovelace.
Selected topics discussed in detail: (a) the solar corona and the solar wind; (b) the propagation of cosmic rays in interplanetary and interstellar space; and (c) the theory of aligned rotating magnetospheres.]

609 Low-Energy Nuclear Physics Fall. 4 credits. Prerequisite: an introductory course in modern physics, including quantum mechanics.
3 lecs. V. Kostroun.
The nuclear interaction. Properties of ground and excited states of nuclei; models of nuclear structure; alpha, beta, gamma radioactivity, low-energy nuclear reactions — resonant and nonresonant scattering, absorption, and fission. At the level of *Introduction to Nuclear Physics* by Enge.

[611 Vision (also Biological Sciences 395) Fall. 3 credits. Prerequisites: Chemistry 104 or 208, Mathematics 106 or 111, Physics 102 or 208, or permission of instructor. Offered alternate years. Not offered 1980–81.
R. K. Clayton.
Study of the mechanisms of seeing, embracing biological, physical, and chemical approaches to the subject.]

612 Nuclear Reactor Theory I Fall. 4 credits. Prerequisites: a year of advanced calculus and some nuclear physics.
3 lecs. K. B. Cady.
Physical theory of fission reactors. Fission and neutron interactions with matter; theory of neutron diffusion; slowing down, and thermalization; calculations of criticality and neutron flux distribution in nuclear reactors. Reactor kinetics. At the level of *Nuclear Reactor Theory* by Lamarsh.

613 Nuclear Reactor Theory II Spring. 3 credits. A continuation of A&EP 612, primarily intended for students planning research in nuclear reactor physics and engineering. Prerequisite: A&EP 612.
3 lecs. K. B. Cady.
The Boltzmann linear transport equation, its adjoint, and their approximate solutions are developed and applied to the heterogeneous neutron chain reactor.

614 Special Topics in Biophysics
W. W. Webb
Topics, credits, and schedule to be announced. Seminars on selected topics of current interest in biophysics research.

615 Membrane Biophysics Spring. 3 credits.
W. W. Webb.
Molecular structure and supramolecular organization of cell membranes. Model membranes and membrane models. Molecular mechanisms of membrane transport, electrophysiology and cell-cell interaction. Physical probes of membrane processes. Dynamics of membrane processes, lateral mobility, diffusion, and flow. Some current problems in cell surface function and organization of specialized membrane macrostructures.

619 Molecular Energy Transfer Spring. 3 credits
T. A. Cool.
Fundamentals of energy transfer by molecular collisions in gases. Energy transfer mechanisms in molecular and chemical lasers. Processes for interconversion of electronic, vibrational, rotational, and translational energy. Intermolecular potential, dispersion forces, multipole moment interactions, repulsive forces.

[622 Electron Optics Spring. 3 credits. Not offered 1980–81.
M. S. Isaacson.
Basic electron optics with emphasis on the fundamental principles of the production and focusing of charged particle beams. Special consideration will be given to the optics appropriate for beam transport and probe forming systems and systems useful in materials characterization. Included will be discussions of the calculation of trajectories in multicomponent optical systems, comprehensive treatments of optical aberrations, and practical considerations of electron optical design.]

633 Nuclear Engineering Fall. 4 credits. Prerequisite: introductory course in nuclear engineering.
K. B. Cady.
The fundamentals of nuclear reactor engineering; reactor siting and safety, fluid flow and heat transfer, control, and radiation protection.

634 Nuclear Engineering Design Seminar
Spring. 4 credits. Prerequisite: A&EP 633.
K. B. Cady.
A group design study of a selected nuclear system. Emphasis is on safety, siting, and radiation protection in the design of nuclear systems.

[636 Seminar on Thermonuclear Fusion Reactors Fall. 3 credits. Prerequisite: basic course in plasma physics or nuclear reactor engineering, or permission of instructor. Not offered 1980–81.
Analysis of various technological and engineering problems in design and construction of fusion reactors. Topics include basic reactor schemes, materials, mechanical and heat transfer problems, radiation and safety, superconducting magnets, energy conversion, plasma impurities, and economics.]

638 Intense Pulsed Electron and Ion Beams: Physics and Technology Spring. 2 credits. Prerequisites: Electrical Engineering 681, 682, and A&EP 606; 607; or equivalent; or permission of instructor.
D. A. Hammer.
Topics include: (1) theoretical aspects of intense electron and ion beams, such as equilibria and stability; (2) technology of intense beam production, such as pulsed-power generator principles, and electron and ion diode operation; and (3) applications of intense beams, such as to controlled fusion, microwave generation, and laser pumping. Extensive discussion of experimental results.

651 Nuclear Measurements Laboratory Spring. 4 credits. Prerequisite: some nuclear physics.
Two 2½-hour afternoon periods plus 1 lec. Staff.
Lectures on interaction of radiation with matter, radiation biology, and nuclear instruments and measurements. Fifteen experiments are available (from which eight are selected) on nuclear physics, radiation instrumentation and measurements, activation analysis, neutron moderation, and reactor physics and engineering; the subcritical reactor assembly and TRIGA reactor are used. At the level of *Nuclear Radiation Detection* by Price and *Radiation Detection and Measurement* by Knoll.

652 Advanced Nuclear and Reactor Laboratory
Spring. 3 credits. Prerequisites: A&EP 651 and 609 or 612. Offered on independent study basis or, with sufficient demand, as a formal course.
Two 2½-hour afternoon periods.
Laboratory experiments and experimental methods in nuclear physics and reactor physics. Ten experiments are available, some using the Zero Power Reactor critical facility.

681–689 Special Topics in Applied Physics
Topics, instructors, and credits to be announced each term. Typical topics include quantum superconducting devices, physics of submicron conductors, nonlinear fluctuators, biophysical processes, molecular fluorescence.

705 Topics in Statistical Physics 3 credits. Prerequisite: general familiarity with statistical mechanics.
M. S. Nelkin.
Selected topics of current interest in statistical physics. For example, in 1976–77 the subject was the variety of anti-intuitive behavior exhibited by nonlinear macroscopic systems driven far from equilibrium; examples were taken primarily from turbulent fluid flow.

711 Principles of Diffraction (also MS&E 610)
Fall. 3 credits. Offered alternate years.
B. Batterman.
Introduction to diffraction phenomena as applied to solid-state problems. Scattering and absorption of neutrons, electrons, and x-ray beams. Diffraction from two- and three-dimensional periodic lattices. Fourier representation of scattering centers, and the effect of thermal vibrations. Phonon information from diffuse x-ray and neutron scattering and Bragg reflections. Diffraction from almost-periodic structures, surface layers, gases, and amorphous materials. Survey of dynamical diffraction from perfect and imperfect lattices.

751, 752 Project 751, fall; 752, spring. Credit to be arranged.
Informal study under the direction of a member of the University staff. Students are offered some research experience through work on a special problem related to their field of interest.

753 Seminar Topics in Applied Physics Fall or spring. 1 credit. Primarily for candidates for the M.Eng (Engineering Physics) degree.
The student attends and writes brief summaries on a minimum of thirteen scheduled University seminars and/or colloquia in technical areas close to the student's main interest.

761 Kinetic Theory (also Electrical Engineering 781) Fall. 3 credits. Prerequisites: Physics 561, 562 or permission of instructor. Offered alternate years.
R. L. Liboff.
See Electrical Engineering 781 for course description.

762 Physics of Solid Surfaces (also MS&E 703)
Spring. 3 credits. Lecture course primarily for graduate and qualified upperclass students. Prerequisite: MS&E 601 or some knowledge of solid-state physics.
An approach to the physics and chemistry of phenomena in metals, semiconductors, and ionic solids related particularly to surface and interfacial effects. Quantum mechanical and kinetic analyses of the interaction of electrons, ions, and molecules with condensed matter. Application and theory of experimental methods in ultrahigh vacuum physics. Materials drawn from research papers and review articles.

Chemical Engineering

101 Nonresident Lectures Fall. Noncredit.
1 lec.
Given by lecturers invited from industry and from selected departments of the University to assist students in their transition from college to industrial life.

110 Mass and Energy Balances Summer. Not offered during the academic year; available during summer. 3 credits. Prerequisite: one year of freshman chemistry. Chemical Engineering 110 is intended for students who cannot take Chemical Engineering 111.
R. G. Thorpe.
Self-paced audiovisual instruction in the material of Chemical Engineering 111. See description under Division of Basic Studies.

111 Mass and Energy Balances Fall. 3 credits. Prerequisite: one year of freshman chemistry or permission of instructor.
3 lecs, 1 computing session. R. G. Thorpe.
See description under Division of Basic Studies.

311 Chemical Engineering Thermodynamics I
Fall. 3 credits.
3 lecs, 1 computing session. W. B. Streett.
A study of the first and second laws, with application to batch and flow processes. Thermodynamic properties of fluids; applications of thermodynamics to compressors, power cycles, refrigeration; thermodynamic analysis of processes.

312 Chemical Engineering Thermodynamics II
Spring. 3 credits.
3 lecs, 1 computing session. K. E. Gubbins.
Thermodynamics of mixtures; phase equilibria and phase diagrams. Estimation methods. Heat effects; chemical equilibria.

321 Materials Spring. 4 credits. Prerequisite: MS&E 261 or equivalent, or permission of instructor.
3 lecs, 1 lab. G. G. Cocks.
Practical aspects of materials: extractive metallurgy, forming and fabrication of metals, some useful alloys, ceramic materials, refractories, selection of materials,

and behavior of materials under service conditions. Laboratory emphasizes microscopical examination of materials; topics include: optics of the microscope, geometrical and optical crystallography and the physical chemical behavior of materials.

410 Reaction Kinetics and Reactor Design Fall. 3 credits. Prerequisite: Chemical Engineering 430.
3 lecs. R. P. Merrill, J. F. Cocchetto.
A study of chemical reaction kinetics and principles of reactor design for chemical processes.

421 Industrial Organic Chemical Processes Spring. 2 credits. Prerequisite: Chemistry 253 or 357.
2 lecs. J. C. Smith.
Study of commercial manufacturing processes for important organic chemicals.

430 Introduction to Rate Processes Fall. 3 credits. Prerequisites: Chemical Engineering 111 and engineering mathematics sequence.
3 lecs, 1 computing session. C. Cohen.
Fundamentals of fluid mechanics and heat transfer; solutions to problems involving viscous flow, heat conduction and convection, friction factors and heat transfer coefficients, macroscopic balances, elementary applications.

431 Analysis of Separation Processes Spring. 3 credits. Prerequisites: Chemical Engineering 430 and familiarity with FORTRAN or PL/I.
3 lecs, 1 computing session. R. G. Thorpe.
Analysis of separation processes involving phase equilibria and rate of mass transfer; some use of the digital computer. Phase equilibria; binary, multicomponent, and extractive distillation; liquid-liquid extraction; gas absorption; crystallization.

432 Chemical Engineering Laboratory Fall. 3 credits. Prerequisites: Chemical Engineering 430, 431.
2 lecs, 1 lab. R. L. Von Berg and staff.
Laboratory experiments in fluid dynamics, heat and mass transfer, other operations. Correlation and interpretation of data. Technical report writing.

433 Project Laboratory Fall or spring. Credit variable. Prerequisite: Chemical Engineering 432.
Special laboratory projects involving bench-scale or pilot-plant equipment.

434 Transport Phenomena Spring. 3 credits. Prerequisites: Chemical Engineering 430 and concurrent registration in 431. Strongly recommended for those interested in graduate study in chemical engineering.
3 lecs. W. L. Olbricht.
An introduction to momentum, heat, and mass transport. Development of governing equations. Solutions of problems involving laminar flow of purely viscous liquids, heat transfer, and convective diffusion.

461 Chemical Process Evaluation Fall. 3 credits.
P. Harriott.
Study of some important chemical processes, covering raw material sources, analysis of reaction conditions, and product purification.

462 Chemical Process Synthesis Spring. 4 credits. Prerequisite: Chemical Engineering 432.
R. L. Von Berg and staff.
A consideration of process and economic alternatives in selected chemical processes; design and assessment.

563 Process Equipment Design and Selection Fall. 3 credits. Prerequisite: Chemical Engineering 430 and 431 or equivalent.
3 lecs. J. C. Smith.
Performance, selection, and design of process equipment; storing, transporting, mixing, heating, and separating fluids and solids. Process development and decision.

564 Design of Chemical Reactors and Multiphase Contracting Systems Spring. 3 credits.
3 lecs. P. Harriott.
Design, scale-up, and optimization of chemical reactors with allowance for heat and mass transfer, nonideal flow, and catalyst aging. Selection of systems for gas-liquid-solid contacting, including stirred tanks, fluidized beds, and fixed beds.

565 Design Project Spring. 3 or 6 credits. Prerequisites: Chemical Engineering 563, 564.
Staff.
Design study and economic evaluation of a chemical processing facility, alternative methods of manufacture, raw material preparation, food processing, waste disposal, or some other aspect of chemical processing.

566 Computer-Aided Process Design Spring. 3 credits. Prerequisite: concurrent registration in 462 or a previous course in process design.
2 lecs, 1 lab. G. F. Scheele.
An introduction to the synthesis and use of computer systems for steady-state simulation of chemical processes.

595, 596 Special Projects in Chemical Engineering Fall or spring. Credit variable.
Research or studies on special problems in chemical engineering.

611 Phase Equilibria Fall. 3 credits. Prerequisite: physical chemistry.
3 lecs. R. G. Thorpe.
A detailed study of the pressure-temperature-composition relations in binary and multicomponent heterogeneous systems where several phases are of variable composition. Prediction of phase data.

621 Petroleum Refining Spring. 3 credits. Prerequisite: Chemical Engineering 461.
3 lecs. H. F. Wiegandt.
A study of processes used to refine petroleum. Recent process developments, including those for selected petrochemicals.

623 Synthetic Fuels Spring. 3 credits.
P. Harriott.
Energy resources and projected consumption. Gasification and liquefaction of coal and oil shale. Synthesis of methane, methanol, and hydrogen. Efficiency and economics of fuel production and use.

627 Nuclear and Reactor Engineering Spring. 2 credits. Prerequisite: permission of instructor.
2 lecs. R. L. Von Berg.
Fuel processing, isotope separation, radioactive waste disposal, radiation damage, shielding, radiation chemistry.

640 Polymeric Materials Fall. 3 credits.
3 lecs. F. Rodriguez.
Chemistry and physics of the formation and characterization of polymers. Principles of fabrication.

641 Physical Polymer Science Spring. 3 credits. Prerequisite: Chemical Engineering 311, 340, or equivalent.
3 lecs. C. Cohen.
Thermodynamic and flow properties of polymer solutions. Phase separation in mixtures. Principal characterization techniques. Viscoelastic and transport properties of bulk polymers. Models of the glass transition. Applications to selected polymer processes.

642 Polymeric Materials Laboratory Spring. 2 or 3 credits. Prerequisite: Chemical Engineering 640.
F. Rodriguez.
Experiments in the formation, characterization, fabrication, and testing of polymers.

644 Microbial Engineering Spring. 3 credits. Prerequisites or corequisites: Chemistry 288 and any course in microbiology.
2 lecs, rec. R. K. Finn.
An advanced discussion of fermentation as a unit process. Topics include sterilization, aeration, agitation, and continuous fermentation.

[645 Industrial Microorganisms Fall. 2 credits. Prerequisites: organic chemistry and physical chemistry. Not offered 1980–81.
R. K. Finn.
A brief introductory course in microbiology for students with a good background in chemistry.]

646 Controlled Cultivation of Microbial Cells Spring. Variable credit. Prerequisite: Microbiology 291.
R. K. Finn.
A projects course. Use of batch and continuous stirred jars to explore the physiology of microorganisms under conditions simulating industrial practice.

647 Wastewater Engineering in the Process Industries Fall. 3 credits. Prerequisites: organic and physical chemistry; Chemical Engineering 430 or equivalent.
R. K. Finn.
Introduction to general and legal problems of pollution control, including some descriptive technology. Major emphasis, however, is on the quantitative engineering aspects of design and operation. Both biological and physical chemical methods, as they apply to the treatment of strong and special wastes from the chemical and allied industries, are discussed.

648 Polymer Processes Spring. 3 credits. Prerequisite: 640 or permission of instructor.
3 lecs. F. Rodriguez.
Production and applications of polymers. Discussion of stabilization and degradation, including processes for recycling and disposal of plastics and related products.

651 Numerical Methods in Chemical Engineering Fall. 3 credits.
3 lecs. G. F. Scheele.
Solution of single and sets of algebraic equations, polynomial approximations, integration, initial and boundary-value ordinary differential equations, partial differential equations, optimization, statistical design of experiments.

661 Air Pollution Control. Fall. 3 credits.
P. Harriott.
Origin of air pollutants, photochemical reactions in the atmosphere. Design of equipment for removal of particulate and gaseous pollutants formed in combustion and chemical processing.

671 Process Control Spring. 3 credits. Prerequisite: Chemical Engineering 430.
3 lecs. J. F. Cocchetto.
Dynamic response of processes and design of control schemes that will maintain output specifications in spite of input disturbances.

672 Process Control Laboratory Spring. 1 credit. Prerequisite: concurrent registration in Chemical Engineering 671.
1 lab. J. F. Cocchetto.
Experiments on controller calibration, dynamics of pneumatic and electronic analogs of process systems, dynamic responses of first and second order open-loop systems, and control of a heat exchanger.

673 Applied Surface Chemistry and Physics Spring. 2 credits.
R. P. Merrill.
Topics in the chemistry and physics of solid surfaces and their applications to applied problems such as

catalysis and corrosion. Specific topics differ each year and students may, with permission of the instructor, take more than one offering of the course.

[680 Chemical Microscopy Fall. 3 credits. Not offered 1980–81.
1 lec, 2 labs. G. G. Cocks.
The use of the light microscope to investigate chemical problems in biological or nonbiological systems. Topics include: the optics of the microscope, types of microscopes (transmission, reflection, polarizing, interference, phase and dark field), the preparation of specimens, qualitative and quantitative analysis, crystallography, and photomicrography.]

[681 Electron Microscopy Fall. 3 credits. Prerequisite: Chemical Engineering 680 or special permission. Not offered 1980–81.
1 lec, 2 labs. G. G. Cocks.
An introductory course designed to teach the student how to use the electron microscope. Topics include optics of the microscope, the use and maintenance of the microscope, specimen preparative techniques (substrates, particulates, replication, microtomy, electron diffraction, and thinning of metals), photomicrographic techniques, and the interpretation of micrographs.]

682 Advanced Chemical Microscopy Spring. Variable credit. Prerequisites: Chemical Engineering 680 and permission of instructor.
G. G. Cocks.
This is primarily a projects course and offers the student the opportunity either to learn more about microscopes and their use or to apply the techniques of microscopy to the investigation of topics or problems of special interest.

[683 Laboratory in Optical Crystallography Fall. Credit variable. This is the laboratory for Geological Sciences 355, but is open to students who want to take the laboratory only. Not offered 1980–81.
2 labs; lec as part of 1 lab. G. G. Cocks.
An introduction to geometrical and optical crystallography for mineralogists, with instruction in the use of the polarizing microscope. Topics include the optics of the polarizing microscope, and geometrical and optical crystallography.]

692, 693, 694 Research Project Fall or spring. 3 credits; additional credit by special permission. Prerequisite: Chemical Engineering 430.
Research on an original problem in chemical engineering.

711 Advanced Chemical Engineering Thermodynamics Spring. 3 credits. Prerequisite: Chemical Engineering 312 or equivalent.
3 lecs. K. E. Gubbins.
Application of general thermodynamic methods to advanced problems in chemical engineering. Evaluation, estimation, and correlation of properties; chemical and phase equilibrium.

713 Applied Chemical Kinetics Spring. 3 credits. Prerequisite: physical chemistry.
R. P. Merrill.
Fundamentals of the kinetics of reacting systems. Collision theory, unimolecular rate theory, transition state theory, and the use of simple statistical models to represent reacting chemical systems are stressed. The application of these concepts to nonideal environments, solvent effects, and reactions on solids is presented with emphasis on catalytic phenomena. The physical chemistry of several industrially important reactive systems are discussed as illustrations.

731 Advanced Transport Phenomena Spring. 3 credits. Prerequisite: Chemical Engineering 434, 751, or equivalent.
3 lecs. C. Cohen.
Viscous laminar flow of Newtonian and Power-Law fluids. Solutions of the Navier-Stokes equations for selected steady- and unsteady-state problems. An integrated presentation of momentum, mass, and heat transfer. Models of mass and heat transfer.

751 Mathematical Methods of Chemical Engineering Analysis Fall. 3 credits.
3 lecs. W. L. Olbricht.
Application of advanced mathematical techniques to chemical engineering analysis. Linear and nonlinear ordinary differential equations, partial differential equations, vector and tensor analysis.

772 Theory of Molecular Liquids Spring. 3 credits. Prerequisite: 711 or equivalent.
K. E. Gubbins.
Theory of intermolecular forces; and equilibrium statistical mechanics for nonspherical molecules. Distribution functions. Applications to thermodynamics of such fluids using integral equation and perturbation theory techniques. Mixture properties, phase diagrams for mixtures with polar or quadrupolar components. Surface properties.

790 Seminar Fall and spring. 1 credit each term.
General chemical engineering seminar required of all graduate students majoring in the Field of Chemical Engineering.

792 Advanced Seminar in Thermodynamics Fall or spring. 1 credit.
K. E. Gubbins.
A forum for talks by graduate students and faculty members on topics of current interest in thermodynamics and statistical mechanics.

891, 892, 893 Thesis Research Fall or spring.
Thesis research for the M.S. degree in chemical engineering.

991, 992, 993, 994, 995 Thesis Research Fall or spring.
Thesis research for the Ph.D. degree in chemical engineering.

Civil and Environmental Engineering

The courses in civil and environmental engineering are listed under the following headings: *Environmental Sensing, Measurement, and Evaluation; Public and Environmental Systems Engineering; Fluid Mechanics and Hydrology; Geotechnical Engineering; Environmental Quality Engineering; Transportation; Structural Engineering; Water Resources Planning and Analysis;* and *Professional Practice.*

A. Environmental Sensing, Measurement and Evaluation

A321 Surveying for CEE Facilities Fall, spring (on demand). 3 credits. Prerequisites: Physics 112, Math 192. Recommended: OR&IE 260 or 270.
2 lecs, 1 lab, evening tests. G. B. Lyon.
This course specifically focuses upon surveying and use of results from surveying operations for planning, design, and construction of civil engineering facilities. Topics include: measurements and data reduction for determination of position, and changes therein, of terrestrial features; measurement quality control; highway curves; earthwork quantities and distribution analysis for minimum construction cost; terrestrial and photogrammetric compilation of topographic maps; use of topographic maps in planning and design; and, selected topics in the acquisition of real estate and the construction of civil and environmental engineering facilities.

A656 Boundary Surveys Spring. 3 credits. Prerequisite: permission of instructor. May not be offered 1980–81.
3 lecs.
Legal principles governing location of land boundaries. Historical development and methods of original land surveys. Retracement and restoration of property corners. Coordinate systems; mineral land surveys; riparian and littoral rights; environmental presentations; responsibilities of licensed surveyors.

A661 Photogrammetry Fall. 3 credits. Prerequisite: permission of instructor. May not be offered 1980–81.
2 lecs, 1 lab.
Terrestrial, aerial, and space photogrammetry. Photograph geometry: tilt and relief displacements; parallax distortions; control requirements; flight planning. Zeiss Stereometric Camera. Stereo plotting, relative and absolute orientation; Balplex, Wild Autographs, and Terragraph plotters. Geometry of remote sensors.

A671 Geodesy Spring. 3 credits. Prerequisite: permission of instructor. May not be offered 1980–81.
3 lecs.
The figure of the earth and the precise determinations of position on or near the earth's surface. Fundamentals of geometric geodesy, physical geodesy, satellite geodesy, and map projections.

A683 Remote Sensing: Environmental Applications Spring. 3 credits. Prerequisite: permission of instructor.
2 lecs, 1 lab. W. R. Philipson.
Applications of remote sensing in various environmental disciplines. Emphasis is on the use of aircraft and satellite imagery for studying surface features in engineering, planning, agriculture, and natural resource assessments.

A685 Physical Environment Evaluation Fall. 3 credits. Prerequisite: permission of instructor.
2 lec, 1 lab. T. Liang.
Physical environment factors affecting engineering planning decisions: climate, soil and rock conditions, water sources. Evaluation methods: interpretation of meteorological, topographic, geologic, and soil maps, airphotos, and subsurface exploration records.

A687 Image Analysis I: Landforms Fall. 3 credits. Prerequisite: permission of instructor.
2 lecs, 1 lab. T. Liang.
Analysis and interpretation of aerial photographs for a broad spectrum of soil, rock, and drainage conditions. Specific fields of application are emphasized.

A688 Image Analysis II: Physical Environments Spring. 3 credits. Prerequisite: CEE A685 or A687.
2 lecs, 1 lab. T. Liang.
Study of physical environments using aerial photographs and other remote sensing methods. Conventional photography, spectral, space, and sequential photography; thermal and radar imageries. Arctic, tropic, arid, and humid climate regions. Project applications.

A691 Project On demand. 1–6 credits.
Staff.
Students may elect to undertake a project in remote sensing and environmental evaluation. The work is supervised by a professor in this subject area.

A692 Research On demand. 1–6 credits.
Staff.
For students who want to study one particular area in depth. The work may take the form of laboratory investigation, field study, theoretical analysis, or development of design procedures.

A694 Special Topics On demand. 1–6 credits.
Staff.
Supervised study in small groups on one or more special topics not covered in the regular courses. Special topics may be of a theoretical or applied nature.

A696 Seminar in Remote Sensing Spring. 1 credit. S-U grades only.
W. R. Philipson.
Presentation and discussion of current research, developments, and applications in remote sensing. Lectures by Cornell staff and invited specialists from government and industry.

A801 Thesis Fall and spring. 1–12 credits.
Students must register for credit with the professor at the start of each term.
A thesis research topic is selected by the student with the advice of the faculty member in charge, and is pursued either independently or in conjunction with others working on the same topic.

B. Public and Environmental Systems Engineering

B301 Microeconomic Analysis (also Economics 311.5) Fall. 4 credits. Prerequisite: one year of college-level mathematics.
R. E. Schuler.
Intermediate microeconomic analysis similar to Economics 311 but emphasizing mathematical techniques. Theory of households, firms, monopoly and competitive markets, distribution and equilibrium, welfare economics. A liberal elective for engineers.

B302 Economic Analysis of Government (also Economics 308) Spring. 4 credits. Prerequisites: one year of college-level mathematics, plus CEE B301 or Economics 311.
R. E. Schuler.
Analysis of government intervention in a market economy. Public goods, public finance, cost-benefit analysis, environmental regulation, and macroeconomic topics.

B303 Engineering Economics and Management Spring. 3 credits. Aimed at juniors and seniors; not intended for students with substantial background in business economics or methods of operations research.
W. R. Lynn.
Intended to give the student a working familiarity with the principles and main analytical techniques for reaching decisions about alternative engineering projects.

B305 Social Implications of Technology Fall. 3 credits. Approved liberal elective. Not open to freshmen.
W. R. Lynn.
Examines selected issues pertaining to the development, implementation, and assessment of technology. Special emphasis is given to social, political, and economic aspects of current problems that have important technological components.

B416 Seminar in Technology Assessment Spring. 3 credits. Open to graduate students and to upperclass undergraduates with permission of instructor.
N. Orloff.
An interdisciplinary seminar dealing with the social consequences of technological developments and means by which technology can be guided in socially beneficial directions.

B614 Legal Methods Spring. 3 credits. Limited to graduate students and to upperclass undergraduates with permission of instructor.
N. Orloff.
An introduction to the structure and operation of our legal system. Development of legal skills and the ability to do one's own basic legal research.

B615 Environmental Law Fall. 4 credits. Limited to graduate students and to upperclass undergraduates with permission of instructor.
N. Orloff.
An introduction to how the legal system handles environmental problems. Study of federal statutes, such as the National Environmental Policy Act, the Clean Air Act, and the Clean Water Act; the regulations issued to implement them; and the important judicial decisions that have been handed down under each.

B617 Public Systems Analysis Fall. 3 credits. Prerequisite: CEE B303 or any introductory systems analysis course.
J. R. Stedinger.
An introduction to the philosophy and applications of systems analysis to public sector problems in transportation, nautral resources, public health, global planning, and energy-environmental quality issues.

B693 Environmental and Water Resources Systems Analysis Colloquium Fall or spring. 1 credit.
Staff.
Lectures in various topics related to environmental or water resources systems planning and analysis.

B791 Environmental and Water Resources Systems Analysis Design Project On demand. Credit variable. Prerequisite: permission of instructor. May extend over two semesters.
Staff.
Design or feasibility study of environmental or water resources systems, supervised and assisted by one or more faculty advisers; individual or group participation. Final report required.

B792 Environmental and Water Resources Systems Analysis Research On demand. Credit variable. Prerequisite: permission of instructor. Preparation must be suitable to the investigation to be undertaken.
Investigations of particular environmental or water resources systems problems.

B794 Special Topics in Environmental or Water Resources Systems Analysis On demand. Credit variable.
Satff.
Supervised study, by individuals or small groups, of one or more specialized topics not covered in regular courses.

C. Fluid Mechanics and Hydrology

C301 Fluid Mechanics I Fall. 4 credits.
Prerequisite: T&AM 203 (may be taken concurrently.)
3 lecs, 1 rec. Staff.
Hydrostatics, the basic equations of fluid flow, potential flow and dynamic pressure forces, viscous flow and shear forces, steady pipe flow, turbulence, dimensional analysis, selection of turbomachinery.

C302 Hydraulic Engineering Spring. 3 credits.
Prerequisite: CEE C301.
2 rec, 1 lab, field trips. Staff.
Steady open channel flow, river modeling, unsteady pipe flow, theory of turbomachinery. Laboratory will include a number of experiments in hydraulic and river engineering. Field trips.

[C609 Descriptive Hydrology Spring. 2 credits. Intended for nonengineering majors. Prerequisite: permission of instructor. Not offered 1980–81.
W. H. Brutsaert.
Introduction to hydrology as a description of the hydrologic cycle and the role of water in the natural environment. Topics include precipitation, infiltration, evaporation, ground water, surface runoff, floods, and droughts.]

C615 Fluid Mechanics II Fall. 3 credits.
Prerequisite: CEE C301.
3 lecs. Staff.
Introduction to tensor analysis, conservation of mass, momentum and energy from a rigorous point of view. Study of exact solutions of the Navier-Stokes equations. Asymptotic approximations at low and high Reynolds numbers. Similitude and modeling. Laminar diffusion of momentum, mass, and heat.

[C618 Dynamic Oceanography Fall. 3 credits.
Prerequisite: CEE C301. Not offered 1980–81.
P. L. -F. Liu.
The statics and dynamics of oceans and lakes. Currents in homogeneous and stratified bodies of water. Tidal motions. Waves in a stratified ocean].

C620 Analytical Hydrology Fall. 3 credits.
Prerequisite: CEE C301.
W. H. Brutsaert.
Physical and statistical analysis related to hydrologic processes. Hydrometeorology and evaporation. Infiltration and base flow. Surface runoff and channel routing. Linear and nonlinear hydrologic systems analysis. Storage routing and unit hydrograph theory.

[C621 Flow in Porous Media and Ground Water Spring. 3 credits. Prerequisite: CEE C301. Not offered 1980–81.
W. H. Brutsaert.
Fluid mechanics and equations of single-phase and multiphase flow; methods of solution. Aquifer hydraulics, pumping wells; drought flows; infiltration, ground water recharge; land subsidence: sea-water intrusion, miscible displacement; transient seepage in unsaturated materials.]

C622 Engineering Micrometeorology Spring. 3 credits. Prerequisite: CEE C301.
3 lecs. W. H. Brutsaert.
Physical processes in the lower atmospheric environment: turbulent transport in the atmospheric boundary layer; surface–air interaction; disturbed boundary layers; radiation. Applications will include sensible and latent heat transfer from lakes; plant canopy flow and evapotranspiration; turbulent diffusion from chimneys and cooling towers; urban climatology; interaction of wind and structures; snow and ice problems.

[C631 Coastal Engineering I Spring. 3 credits.
Prerequisite: CEE C301. Not offered 1980–81.
3 lecs. P. L. -F. Liu.
Linear wave theory, wave generation by wind, analysis of fluid forces on floating and fixed coastal structures, and modification of waves and currents by these structures, coastal processes and coastal sediment motion.]

[C633 Coastal Engineering II Fall. 3 credits.
Prerequisite: CEE C631. Not offered 1980–81.
3 lecs. P. L. -F. Liu.
Review of gravity wave theories, applicability of different wave theories to engineering problems, wave energy transmission, tsunamis, boundary value problems in wave hydrodynamics, behavior of submerged and floating bodies, harbor agitations, ship waves.]

C641 Environmental Fluid Mechanics I Fall. 3 credits. Prerequisite: CEE C301.
3 lecs. G. H. Jirka.
Introduction mass and heat transport processes due to pollutant discharges into the environment. Turbulent diffusion equation and its solution for instantaneous and continuous releases. Concept of longitudinal dispersion in shear flow. Applications to pollutant transport prediction in lakes, rivers, estuaries, and coastal zones, as well as the atmosphere. Relative role of hydrodynamic transport to reaction kinetics. Exchange processes for mass and heat at the air-water interface. Convective transport due to density currents. Jet mixing and the design of outfall structures.

C642 Environmental Fluid Mechanics II Spring. 3 credits. Prerequisite: CEE C641 or permission of instructor. Offered alternate years.
3 lecs. G. H. Jirka.
Mechanics of discretely and continuously stratified fluids: internal waves, density currents, blocking,

selective withdrawal, and internal jumps. Interfacial stability and mixing. Observed characteristics of turbulent fluid flow in environmental applications, including interaction with buoyancy. Integral techniques for self-similar flows: jets, plumes, and mixing layers. Experimental approaches to environmental fluid problems.

C643 Unsteady Hydraulics Spring. 3 credits. Prerequisite: CEE C302 or permission of instructor.
J. A. Liggett.
The physical and mathematical basis for unsteady processes in hydraulic engineering, especially unsteady open channel flow. Water hammer, unsteady sediment transport, long waves on large bodies of water, circulation. Numerical methods of solution.

[C651 Environmental Planning and Operation of Energy Facilities Spring. 3 credits. Mixed lecture/seminar format. Prerequisites: CEE C641 or equivalent. Offered alternate years. Not offered 1980–81.
G. H. Jirka.
Survey of analytical methodologies for predicting and controlling the environmental impacts of individual energy facilities or of energy systems. Estimation of construction and operating impacts: pollutant sources, models for pollutant dispersal, modeling the relationships of pollutant concentration and ecological, health, and socioeconomic damages. Pollutant abatement strategies and transient releases techniques. Models for regional energy facility siting.]

C691 Project On demand. Variable credit.
Hours to be arranged. Staff.
The student may elect a design problem or undertake the design and construction of special equipment in the fields of fluid mechanics, hydraulic engineering, or hydrology.

C693 Hydraulics Seminar Spring. 1 credit. Open to undergraduates and graduates and required of graduate students majoring in hydraulics or hydraulic engineering.
Staff.
Topics of current interest in fluid mechanics, hydraulic engineering, and hydrology.

C694 Special Topics in Hydraulics On demand. Credit variable.
Staff.
Special topics in fluid mechanics, hydraulic engineering, or hydrology.

C744 Experimental and Numerical Methods in Hydraulics and Hydrology On demand. 2 credits.
Staff.
Methods used in planning and conducting laboratory and field experiments and in performing numerical analysis. Specific subject matter varies according to the interests of students and staff.

C792 Research in Hydraulics On demand. Variable credit.
Staff.
The student may select an area of investigation in fluid mechanics, hydraulic engineering, or hydrology. The work may be either experimental or theoretical in nature. Results should be submitted to the instructor in charge in the form of a research report.

D. Geotechnical Engineering

D301 Introductory Soil Mechanics Spring. 3 credits.
2 lecs, 1 lab/tutorial. T. D. O'Rourke.
Soil as an engineering material. Chemical and physical nature of soil. Engineering properties of soil. Stresses and stress analysis in soil. Introduction to stability, earth pressure, and other design problems. Introduction to laboratory testing.

D606 Foundation Engineering Fall. 3 credits. Prerequisite: CEE D301.
3 lecs, optional tutorial. F. H. Kulhawy.
Soil exploration, sampling, and in-situ testing techniques. Bearing capacity, stress distribution, and settlement. Design of shallow and deep foundations. Compaction and site preparation. Seepage and dewatering of foundation excavations.

D607 Retaining Structures and Slopes Spring. 3 credits. Prerequisite: CEE D301.
3 lecs, optional tutorial. T. D. O'Rourke, F. H. Kulhawy.
Earth pressure theories. Design of rigid, flexible, braced, tied back, slurry, and reinforced earth walls. Stability of excavation, cut, and natural slopes.

D631 Highway Engineering (also Agricultural Engineering 491) Fall. 3 credits. Prerequisite: CEE D301 or permission of instructor.
2 lecs, 1 lab. L. H. Irwin.
See Agricultural Engineering 491 for course description.

D632 Bituminous Materials and Pavement Design (also Agricultural Engineering 492) Spring. 3 credits. Prerequisite: CEE D631 or permission of instructor.
2 lecs, 1 lab. L. H. Irwin.
See Agricultural Engineering 492 for course description.

D691 Design Project in Geotechnical Engineering On demand. 1–6 credits.
Students may elect to undertake a design project in geotechnical engineering. The work is supervised by a professor in this subject area.

D693 Seminar in Geotechnical Engineering Fall or spring.
Staff.
Presentation and discussion of topics of current research and practice in geotechnical engineering.

D694 Special Topics in Geotechnical Engineering On demand. 1–6 credits.
Staff.
Supervised study of special topics not covered in the formal courses.

D710 Engineering Behavior of Soils Fall. 3 credits. Prerequisite: CEE D301. Seniors must have permission of instructor.
3 lecs. Staff.
Detailed study of physiochemical nature of soil. Stress states and stress-strain-time behavior. In-depth evaluation of the strength, compressibility, and permeability of natural soils. Study of special deposits such as sensitive, organic, frozen, and man-made soils.

D711 Rock Engineering Fall. 3 credits. Prerequisite: CEE D301 or permission of instructor. Recommended: introductory geology.
2 lecs, 1 lab. F. H. Kulhawy.
Geological and engineering classifications of intact rock, discontinuities, and rock masses. Laboratory and field evaluation of properties. Stress states and stress analysis. Design of foundations on and openings in rock masses. Analysis of the stability of rock slopes.

D712 Graduate Soil Mechanics Laboratory Fall. 3 credits. Prerequisite: CEE D710.
T. D. O'Rourke.
Introductory through advanced techniques for laboratory measurement of soil properties. Emphasis on strength, compressibility, and permeability tests. Critical evaluation of laboratory methodology.

[D714 Advanced Foundation Engineering Spring. 3 credits. Prerequisite: CEE D606. Not offered 1980–81.
3 lecs. Staff.
A continuation of CEE D606 with detailed emphasis on special topics in soil-structure interaction. Typical topics include: lateral and pullout loading of deep foundations, pile group behavior, foundations for offshore structures, pile-driving dynamics, foundations for special structures.]

D715 Soil Dynamics Spring. 3 credits. Prerequisite: permission of instructor.
3 lecs. Staff.
Principles of vibration under harmonic and transient loading. Wave propagation. Dynamic response of soils and its measurement. Analytical models for harmonic, transient, and earthquake loading. Design examples of foundations and embankments.

D717 Embankment Dam Engineering Spring. 2 credits. Prerequisites: CEE D607 and D711, or permission of instructor.
2 lecs. F. H. Kulhawy.
Principles of analysis and design for earth and rockfill dams. Materials, construction methods, internal and external stability, seepage and drainage, performance monitoring, abutment and foundation evaluation. Introduction to tailings dams.

[D718 Case Studies in Geotechnical Engineering Spring. 3 credits. Prerequisites: CEE D606 and D607. Not offered 1980–81.
Staff.
Study of case histories in geotechnical engineering. Critical evaluation of successful and unsuccessful projects. Oral presentations and engineering report evaluation of each case.]

[D719 Tunnel Engineering Spring. 2 credits. Prerequisites: CEE D607 and D 711. Not offered 1980–81.
2 lecs. F. H. Kulhawy, T. D. O'Rourke.
Principles of analysis and design for earth and rock tunnels. Materials, construction methods, stability and support systems, deformations, and performance monitoring.]

D792 Research and Geotechnical Engineering On demand. 1–6 credits.
Staff.
For the student who wants to pursue a particular geotechnical topic in considerable depth.

E. Environmental Quality Engineering

E301 Environmental Quality Engineering Spring. 3 credits. Prerequisite: CEE C301.
J. J. Bisogni, J. M. Gossett.
Introduction to the engineering aspects of environmental quality control. Emphasis on water quality control concepts, theory, and methods. Elementary analysis and design applicable to water supply and distribution and to wastewater and storm-water collection systems. Introduction to processes underlying water and wastewater treatment. Effects of wastewater on natural waters.

E604 Assimilation of Pollutants in Natural Waters Fall. 3 credits. Prerequisite: CEE E301 or permission of instructor.
3 lecs.
Assimilation and transport of pollutants in the aquatic environment. Emphasis on the physics, chemistry, and biology that form the basis for mathematical description of the assimilation phenomenon in natural waters.

E610 Chemistry of Water and Wastewater Fall. 3 credits. Prerequisite: one year of college chemistry or permission of instructor.
3 lec-recs. J. M. Gossett.
Principles of physical, organic, inorganic, and biological chemistry applicable to the understanding, design, and control of water and wastewater treatment processes and to reactions in receiving waters.

E611 Aquatic Chemistry Spring. 3 credits. Prerequisite: CEE E610 or Chemistry 287–288.
3 lecs. J. J. Bisogni.
Chemical equilibria in natural aquatic systems, including water and wastewater treatment systems. Chemical thermodynamics, acid-base systems, oxidation-reduction systems, coordination chemistry, solid-liquid-gas interfaces with regard to precipitation, dissolution, and adsorption. Chemical-biological interfaces in natural systems. Emphasis on phenomena, mathematical solution of chemical equilibria, and application to engineering management of water quality.

[E630 Solid Waste Management and Resource Recovery Spring. 3 credits. Limited to seniors and graduate students. Not offered 1980–81.
3 lec-discs.
Sources, nature, and properties of municipal and industrial solid wastes. Mechanical, biological, and thermal processing methods for disposal of solid wastes and for recovery of material and energy from them]

E633 Environmental Quality Management Fall; spring on demand. 3 credits (4 with approval of instructor). For upperclass or graduate students. May not be offered 1980–81.
2 lec-discs. L. B. Dworsky.
An introduction to environmental quality management; nature, cause, and control of environmental problems; interaction of physical, social, and cultural environments; emphasis on the interdependent social, economic, developmental, and environmental issues confronting society.

[E634 Air Quality Control Spring. 3 credits. Limited to seniors and graduate students. Not offered 1980–81.
3 lec-discs.
An introduction to air quality and air pollution problems. Sources, characteristics, and effects of specific air pollutants; their dispersion and interactions in the atmosphere. Air quality standards and regulations. Air pollution control methods.]

[E636 Environmental Effects of Energy Conversion Fall. 3 credits. Limited to upperclass and graduate students. Not offered 1980–81.
3 lec-discs.
Characteristics of airborne, waterborne, and solid wastes generated in energy-conversion processes. Estimation of the potential impacts of these wastes on the physical environment. Behavior and fate of these wastes in the environment and their effects on receptors. Regulatory and Engineering aspects of waste control. Emphasis is on wastes and phenomena related to fossil, nuclear, and refuse-derived fuels.]

E638 Sludge Treatment, Utilization, and Disposal Spring. 3 credits. Prerequisites: CEE E301 and E610 or permission of instructor.
R. I. Dick.
An analysis of the quantity and quality of residues produced from wastewater treatment facilities as a function of process design and operation; the alternatives for reclamation or ultimate disposal of residues with assessment of potential environmental impacts and factors influencing the magnitude of those impacts; the fundamental factors influencing performance of treatment processes for altering sludge properties prior to ultimate disposal; and considerations in selection and integration of sludge management processes to approach optional design.

E693 Environmental Quality Engineering Seminar Fall or spring. 1 credit. Required of graduate students majoring or minoring in sanitary engineering. Open to undergraduates who have received permission of the instructor.
Presentation and discussion of current topics and problems in sanitary engineering and environmental quality engineering.

E712 Water Chemistry Laboratory Fall. 1 credit. Enrollment limited. Prerequisites: CEE E610 (students may enroll concurrently in CEE E610) and permission of instructor.
J. M. Gossett.
Laboratory methods for analysis of pollutants in water and wastewater.

E715 Chemical and Physical Phenomena and Processes Fall. 4 credits. Prerequisite: CEE E610 or permission of instructor.
3 lecs, 1 lab. J. J. Bisogni.
Theoretical and engineering aspects of chemical and physical phenomena and processes applicable to the removal of impurities from water, wastewater, and industrial wastes, and to their transformation in receiving waters. Analysis and design of treatment processes and systems. Residuals control and treatment. Pertinent laboratory studies.

E716 Biological Phenomena and Processes Spring. 4 credits. Prerequisite: CEE E715 or permission of instructor.
3 lecs, 1 lab. J. M. Gossett.
Theoretical and engineering aspects of biological phenomena and processes applicable to the removal of impurities from water, wastewater, and industrial wastes, and to their transformation in receiving waters. Biokinetic analysis and design of biological treatment process. Pertinent laboratory studies.

E791 Design Project in Sanitary Engineering On demand. Variable credit. Prerequisite: CEE E301 or equivalent.
Staff.
The student will elect or be assigned a problem in the design of water or wastewater treatment processes or plants or wastewater disposal systems; or a laboratory project.

E792 Sanitary Engineering Research On demand. Variable credit. Prerequisites will depend on the particular investigation to be undertaken.
Staff.
For the student who wants to study a problem in greater depth than is possible in formal courses. Study may be any combination of literature, laboratory, or computational research.

E794 Special Topics in Sanitary Engineering On demand. Variable credit.
Hours to be arranged. Staff.
Supervised study in special topics not covered in formal courses.

E801 Thesis Fall and spring. 1–12 credits.
Students must register for credit with the professor at the start of each term.
A thesis research topic is selected by the student with the advice of the faculty member in charge, and is pursued either independently or in conjunction with others working on the same topics.

F. Transportation

F301 Introduction to Transportation Engineering Fall. 3 credits.
A. H. Meyburg.
Introduction to technological, economic, and social aspects of transportation. Emphasis on the form and functioning of transportation systems and their components. Vehicle and system technology, traffic flow and control, terminal operations, supply-demand interactions, system planning and management, and institutional issues.

F621 Urban Transportation Planning Fall. 4 credits.
A. H. Meyburg.
The urban transportation problems: its roots, manifestations, and implications; the systems analysis approach to transportation; the demand and supply side of transportation; the urban transportation planning process and its modeling components; generation and evaluation of alternatives. A laboratory period is designed for study-team research.

F623 Travel Theory and Applications Spring. 3 credits. Prerequisite: CEE F621 or permission of instructor.
A. H. Meyburg.
This course concentrates on new methods for estimating and predicting travel demand. In particular, it will consider techniques based on a treatment of the individual as an economic or psychological decision-making unit. Theoretical background to the models, empirical estimation, measurement of atrributes and practical applications will all be considered. Practical problems and directions of present and future research will be outlined. Survey sampling will be introduced.

F624 Transportation Systems Analysis Fall. 3 credits. Prerequisites: CEE F301, OR&IE 320 or equivalent.
M. A. Turnquist.
Application of operations research and systems analysis techniques to transportation systems, both passenger and freight. Network flows, routing and scheduling, technology selection, and terminal operation.

F625 Transportation Systems Design Spring. 3 credits. Prerequisite: CEE F624.
M. A. Turnquist.
Techniques for design of transportation systems, including networks of fixed facilities and route networks. Time-staging of improvements, use of low-capital cost options, and the role of demonstration projects. Evaluation of alternative designs.

F643 Operations, Design, and Planning of Public Transportation Systems Spring. 3 credits.
G. P. Fisher.
A study of mass transportation of the past and present, innovative forms of mass and individual transportation in urban areas. The financing and organization of mass transportation; the "free transit" versus fares dilemma. Planning for mass transportation: special applications, implementation of plans, planning transportation in new towns.

F645 Freight Transportation Spring. 3 credits.
G. P. Fisher.
Transportation planning methodology for interurban and intraurban freight movements. Relationship to the urban transportation planning process. Problem identification, solution strategies, analysis techniques. Freight demand analysis. Alternative technologies in view of energy, efficiency, and environmental impacts.

F646 Transportation Economics Spring. 3 credits. Prerequisite: CEE B301 or equivalent.
M. A. Turnquist.
Economic analysis of freight and passenger transportation systems. Pricing and regulation. Elements of cost-benefit analysis and evaluation of public investment and subsidization. Consideration of national transportation policy.

F791 Transportation Design Project On demand. Variable credit.
Staff.
Design or feasibility study of transportation systems, supervised by one or more faculty advisers. Individual or group participation.

F792 Transportation Research On demand. Variable credit.
Staff.
In-depth investigation of a particular transportation planning or engineering problem mutually agreed upon between the student and one or more faculty members.

F793 Transportation Colloquium Fall or spring. 1 credit.
Lectures in various topics related to transportation planning and analysis.

F794 Special Topics in Transportation Fall or spring. Variable credit.
Staff.
Consideration of subject matter not covered in depth in regular courses. Topic(s) will vary from year to year, but may include terminal operations, airport planning and design, traffic flow theory, marine transportation, etc.

See also:
D631 Highway Engineering (Agricultural Engineering 491) [See description under Agricultural Engineering 491.]

G. Structural Engineering

G301 Structural Engineering I Fall. 4 credits.
Prerequisite: T&AM 202.
3 lecs, one 2-hour lab; evening exams. P. Gergely.
Fundamental concepts of structural engineering. Behavior, analysis, design, structural planning. Loads, structural form, statically determinate analysis, approximate analysis of indeterminate systems. Behavior and design of steel and concrete members.

G302 Structural Engineering II Spring. 4 credits.
Prerequisite: CEE G301.
3 lecs, one 2-hour lab; evening exams. W. McGuire.
Fundamentals of statically indeterminate structures. Moment-area and virtual work methods of displacement computation. Matrix flexibility and stiffness and moment distribution analysis methods. Plastic analysis of steel frames. Computer applications to practical structures.

G303 Structural Engineering III Fall. 4 credits.
Prerequisites: CEE G302 or permission of instructor; CEE G351 is also required, but may be taken concurrently.
Evening exams. T. Pekōz.
Continues the study of the behavior and design of steel and concrete. Structural elements, connections, and systems.

G304 Structural Engineering IV Spring. 4 credits.
Prerequisite: CEE G303.
M. D. Grigoriu.
Intended to develop an understanding of the structural design process. Comprehensive design project. Lectures on preliminary design, composite construction, prestressed concrete, and various structural systems such as bridges, roofs, and tall buildings.

G305 Structural Behavior Laboratory Spring. 2 credits. Prerequisite (may be taken concurrently instead): CEE G302.
R. N. White.
A lab course on behavior of structures, utilizing small-scale models. Elastic, inelastic, and nonlinear behavior of structural components and systems. Projects.

G351 Engineering Materials Fall. 3 credits.
2 lecs, 1 lab. F. O. Slate.
Engineering properties of concrete, steel, wood, and other structural materials. Design characteristics and significance of test results of materials used in engineering works. Extensive laboratory testing and report writing.

G608 Timber Engineering Spring. 1 credit.
Prerequisite: CEE G303.
R. N. White.
Structural properties of timber. Timber tension members, beams, and beam-columns. Glued-laminated timber design. Connection behavior and design. Special timber structural systems.

G610 Fundamentals of Structural Mechanics Fall. 3 credits. Prerequisite (may be taken concurrently instead): CEE G303.
Staff.
Theory of elasticity, energy principles, plate flexure, failure theories, inelastic stress-strain relationships, stress concentration, introduction to fracture, fatigue.

G612 Advanced Structural Analysis Fall. 3 credits. Prerequisites: CEE G302 and computer programming.
A. R. Ingraffea.
Direct stiffness and flexibility methods in matrix formulation, use of standard analysis programs, error detection, substructuring, and special analysis procedures.

G614 Structural Model Analysis and Experimental Methods Fall. 3 credits.
2 lecs, 1 lab. R. N. White.
Dimensional analysis and similitude. Model materials, fabrication, loading, and instrumentation techniques. Experimental stress analysis.

G652 Advanced Plain Concrete Spring. 3 credits. Prerequisite: CEE G351 or equivalent.
2 lecs, conferences. F. O. Slate.
Topics such as history of cementing materials, air entrainment, light-weight aggregates, petrography, durability, chemical reactions, properties of aggregates, and construction. Relationships among internal structure, physical properties, chemical properties, and mechanical properties.

[G653 Structure and Properties of Materials Spring. 3 credits. Limited to graduate students in engineering or physical sciences, or undergraduates by permission of instructor. Offered alternate years. Not offered 1980–81.
2 lecs, conferences. F. O. Slate.
Internal structure from amorphous to crystalline state. Forces holding matter together versus forces causing deformation and failure. Correlation of internal structures with physical and mechanical properties. Applications to various engineering materials.]

G654 Low-cost Housing Primarily for Developing Nations Spring. 3 credits. Offered alternate years.
2 lecs, conferences. F. O. Slate.
A multidisciplinary course. Students study intensively, usually in their own discipline, for a term project, while also being introduced to problems and approaches of other disciplines. Engineers investigate the technological aspects of the subject and other aspects that influence technological decisions, such as cultural and economic factors.

[G655 Low-cost Housing for Developing Nations — Workshop for Physical Planning, Site Selection, and Design Spring. A mixed class of advanced civil engineering and architecture students. Offered alternate years. Not offered 1980–81.
F. O. Slate.
Discussions and workshops on physical planning, site selection, choice of materials, and detailed design of individual structures and groupings.]

G693 Structural Engineering Seminar Fall or spring. 1 credit. Limited to qualified seniors and graduate students.
Staff.
Presentation of topics of current interest in the field of structures.

G709 Engineering Fracture Mechanics Spring. 3 credits. Prerequisite: CEE G713 or permission of instructor. Offered alternate years. Will be offered 1980–81.
2 lecs, 1 lab. A. R. Ingraffea.
Fundamentals of fracture mechanics theory. Energy and stress-intensity approaches to fracture. Mixed-mode fracture. Fatigue crack propagation. Finite and boundary element methods in fracture mechanics. Introduction to elastic-plastic fracture mechanics. Laboratory techniques for fracture toughness testing of metals, concrete, and rock.

G711 Stability: Theory and Design Spring. 3 credits.
T. Pekōz.
Analysis of elastic and plastic stability. Determination of buckling loads and postbuckling behavior of columns. Solid and open web columns with variable cross section. Beam columns. Frame buckling. Torsional-flexural buckling. Lateral buckling of beams. Buckling loads and postbuckling behavior of plates, shear webs, and shells. Critical discussion of current design specification.

G713 Finite Element Analysis Spring. 3 credits. Prerequisites: CEE G610 and G612.
J. F. Abel.
Theoretical and conceptual bases for finite elements in structural mechanics. Development of element relationships and system solution techniques for analysis of bars, beams, planar structures, solids, plates, and shells.

G715 Structural Reliability and Safety Fall. 3 credits. Prerequisite: CEE G303. Offered alternate years.
M. D. Grigoriu.
Probabilistic models for loads, load combinations, and strength of members and structural systems. Structural reliability. Design-code provisions for safety.

G716 Prestressed Concrete Structures Fall. 3 credits. Prerequisite: CEE G303. Recommended: CEE G304.
3 lecs. A. H. Nilson.
Behavior, analysis, design of pretensioned and posttensioned prestressed concrete structures. Partial prestressing. Strength, serviceability, structural efficiency of beams, slabs, tension and compression members, frameworks, bridges.

G717 Advanced Reinforced Concrete Spring. 3 credits. Prerequisite: CEE G303. Recommended: CEE G304.
3 lecs. A. H. Nilson.
Behavior, analysis, design of reinforced concrete structures. Strength, safety, serviceability, structural efficiency. Beams, columns, slabs, frameworks, composite members, ground-supported slabs, shear walls, deep beams, folded plates.

G718 Advanced Design of Metal Structures Fall. 3 credits. Prerequisite: CEE G303.
W. McGuire.
Behavior and design, with emphasis on connections, plate girders, and cold-formed steel structures. Torsion of steel members. Fatigue and fracture.

G719 Advanced Behavior of Metal Structures Spring. 3 credits. Prerequisite: CEE G303.
W. McGuire.
Behavior of beams, beam-columns, and single and multistory frames. Analysis and design of tall building systems. Cable-supported structures.

G720 Shell Theory and Design Spring. 3 credits.
P. Gergely.
Fundamentals of practical shell theory. Differential geometry of surfaces; membrane and bending theory of shells; analysis and design of cylindrical shells, polygonal domes, and paraboloids.

G722 Structural Design for Dynamic Loads Spring. 3 credits.
P. Gergely.
Analysis, design, and behavior of structures subjected to dynamic effects, with emphasis on earthquake-resistant design.

[G732 Optimum Structural Design Fall. 3 credits. Offered alternate years. Not offered 1980–81.
Design of minimum weight or cost structures. Includes full-stressed design, classical, minimization procedures, and mathematical programming methods.]

[G733 Numerical Methods in Structural Engineering Fall. 3 credits. Prerequisites: CEE G610 and G612. Offered alternate years. Not offered 1980–81.
J. F. Abel.
Numerical techniques for structural and geotechnical engineering, such as residual, variational, finite-difference, and finite-element methods. Selected numerical analysis topics and solution algorithms with emphasis on linear equations and eigenvalue problems.]

[G734 Advanced Topics in Finite Element Analysis Fall. 3 credits. Prerequisite: G713. Offered alternate years. Not offered 1980–81.
J. F. Abel.
Lectures and colloquia on selected advanced topics and research in progress, including dynamics, nonlinear analysis, shells, fracture mechanics, fluid dynamics, and computer graphics.]

G757 Civil and Environmental Engineering Materials Project On demand. 1–3 credits.
F. O. Slate.
Individual projects or reading and study assignments involving engineering materials.

G791 Design Project in Structural Engineering Fall or spring. Variable credit.
Students may elect to undertake a design project in structural engineering. The work is supervised by a professor in this subject area.

G792 Research in Structural Engineering On demand. Variable credit.
Hours to be arranged. Staff.
Pursuit of a branch of structural engineering further than can be done in regular courses. Theoretical or experimental investigation of suitable problems.

G794 Special Topics in Structural Engineering On demand. Variable credit.
Hours to be arranged. Staff.
Individually supervised study or independent design or research in specialized topics not covered in regular courses.

G801 Thesis Fall and spring. 1–12 credits.
Students must register for credit with the professor at the start of each term.
A thesis research topic is selected by the student with the advice of the faculty member in charge, and is pursued either independently or in conjunction with others working on the same topic.

H. Water Resources Planning and Analysis

H615 Water Resources Problems and Policies Fall. 3 credits. Intended primarily for graduate engineering and nonengineering students but open to qualified upperclass students. Prerequisite: permission of instructor.
Lec-disc. L. B. Dworsky.
Historical and contemporary perspectives of water problems, organization, and public policies.

H624 Stochastic Hydrologic Modeling Fall. 3 credits. Prerequisite: OR&IE 260.
J. R. Stedinger.
Develops statistical techniques in time and frequency domain used to analyze and model stochastic processes. Lectures examine Box-Jenkins, fractional-Brownian noise and other steamflow models, drought and flood frequency estimation, parameter estimation in dynamic systems, and analysis of simulation output.

H626 Water Quality Modeling Spring. 3 credits. Prerequisites: CEE B303 or Agricultural Engineering 475; CEE C651 or CEE E604 recommended.
D. P. Loucks.
Predictive models of the behavior of biological and chemical substances in bodies of water and in surface runoff. Regional management of water quality.

H628 Water Resources Systems Planning I Fall. 3 credits. Prerequisite: CEE B303 or equivalent.
D. P. Loucks.
Application of deterministic optimization and simulation techniques in water resources planning. River-basin modeling, including irrigation planning and operation, hydropower capacity development, flow augmentation, and flood control and protection.

H629 Water Resource Systems Planning II Spring. 3 credits. Prerequisites: CEE H628 and H624 or permission of instructor.
D. P. Loucks.
Optimization and simulation methods for water resource planning under hydrological, technological, and political uncertainty. Concepts of system reliability, vulnerability, resilience, stability, and robustness.

K. Professional Practice

K301 Numerical Solutions to Civil Engineering Problems Fall. 3 credits.
Introduction to numerical and computer methods through consideration of typical problems drawn from a number of disciplines within civil and environmental engineering. Topics include computer use, computer programming, data handling, numerical analysis, and the role of computing in the civil engineering profession.

K510 Civil and Environmental Engineering Design Project I Fall. 3 credits. Required for students in the M.Eng.(Civil) program.
School faculty and visiting engineers.
Design of major civil engineering project. Planning and preliminary design in fall term; final design in January intersession (CEE K511).

K511 Civil and Environmental Engineering Design Project II Spring (work done during January intersession). 3 credits. Required for students in the M.Eng.(Civil) program. Prerequisite: CEE K510.
School faculty and visiting engineers.
A continuation of CEE K510.

K521 Professional Practice in Engineering Spring. 3 credits. Required for and limited to students in the M.Eng.(Civil) program.
W. R. Lynn.
Introduction to nontechnical aspects of engineering practice: legal, financial, social, and ethical aspects; personnel management; communications; professional organizations.

See also:
CEE B614 Legal Methods 3 credits.

K531 Engineering Ethics Fall or spring. 3 credits. May not be offered 1980–81.
Introduction to ethical issues arising in the discharge of the professional engineer's obligations to clients and to the public. Systematic analysis of the implications of these issues in realistic engineering situations. Topics selected from the literature and from the experience of engineers and of students.

K601 Numerical Solutions to Civil Engineering Problems Fall. 3 credits.
Introduction to numerical and computer methods through consideration of typical problems drawn from a number of disciplines within civil and environmental engineering. Topics include computer use, computer programming, data handling, numerical analysis at the graduate level, and the role of computing in the civil engineering profession.

Computer Science

The Department of Computer Science is organized as an intercollege department in the College of Arts and Sciences and the College of Engineering.

100 Introduction to Computer Programming Fall or spring. 3 credits. S-U grades optional. Students who plan to take both Computer Science 101 and 100 must take 101 first.
2 lecs, 1 rec (optional), 3 evening exams, final.
An introduction to elementary computer programming concepts. Emphasis is on techniques of problem analysis, algorithm and program development. The subject of the course is programming, not a particular programming language. The principal programming language is PL/I; FORTRAN is introduced and used for final problems. The course does not presume previous programming experience. An introduction to numerical computing is included, although no college-level mathematics is presumed. Programming assignments are tested and run on interactive, stand-alone microcomputers.

101 The Computer Age Spring. 3 credits. S-U grades optional. Credit cannot be granted for both Computer Science 100 and 101 unless 101 is taken first.
2 lecs, 1 rec.
Introduction to computer science and programming for students in nontechnical areas. Topics include the history of computation; microtechnology; the retrieval and transmission of information; scientific computing; computer graphics, art, and music; robotics, natural language processing, and machine intelligence. Students become acquainted with the notion of an algorithm by writing several PL/C programs. The amount of programming is about half of that taught in Computer Science 100. Each student writes a term paper on some aspect of computing. The aims of the course are to make the student an intelligent consumer of what the computer has to offer and to develop an appreciation of algorithmic thinking.

102 Introduction to FORTRAN Programming Fall or spring, weeks 1–5 only. 1 credit. S-U grades optional. Credit will not be granted for both Computer Science 100 and 102 unless 102 is taken first.
Elementary programming concepts. Laboratory problems using FORTRAN IV language.

103 Introduction to PASCAL Fall or spring, weeks 6–9 only. 1 credit. Prerequisite: Computer Science 100 or equivalent programming experience. S-U grades optional.
Variables; data types and type definitions; scalar, set, array, and record types; language constructs for systematic programming; files; procedures and functions. Several programming assignments.

104 Introduction to APL Programming Fall or spring, weeks 2–5 only. 1 credit. Prerequisite: Computer Science 100 or equivalent programming experience. S-U grades optional.
Introduction to interactive terminal computing using the APL language.

107 Introduction to Interactive Computing with CMS Fall or spring, weeks 2–5 only. 1 credit. Prerequisite: Computer Science 100 or equivalent programming experience. S-U grades only.
Concepts of interactive computing, using the editor, data management, utility commands, remote job submission, interactive language processors, and the EXEC facility.

108 Introduction to Statistical Packages Fall or spring, weeks 10–13 only. 1 credit. S-U grades only.
Discussion of the wide range of procedures and data transformation facilities provided by statistical program packages. Topics covered include data preparation and formatting, program control cards, JCL, and hints for debugging.

109 Multistep Job Processing and JCL Fall or spring, weeks 6–9 only. 1 credit. Prerequisite: Computer Science 100 or equivalent programming experience. S-U grades only.
Outline of HASP and OS systems currently implemented. Topics include job control language for

using tapes, disks, catalogued procedures and symbolic parameters, and HASP commands for special processing.

211 Computers and Programming Fall or spring. 3 credits. Prerequisite: Computer Science 100 or equivalent programming experience.
2 lecs, 1 lab.
Intermediate programming in PL/I: procedures, block structures, on conditions, recursion. Introduction to data structures and program analysis and simulation. Programming assignments for a variety of applications.

280 Discrete Structures Fall. 4 credits. Prerequisite: Computer Science 211 or permission of instructor.
3 lecs.
Mathematical aspects of programming and computing. Induction, logical proof, and discrete structures used in programs. Introducing recursive functions, relations, homomorphisms, partially ordered sets, the predicate calculus, and concepts from automata and computability theory.

305 Social Issues in Computing Fall. 3 credits. Prerequisite: Computer Science 100 or 101 or permission of instructor.
2 lec-sem.
The economic, political, legal, and cultural impact of computers and computer-related technology. The role of computers in coordinating diversity and reducing disorder. Effect of computers on the individual. Data banks and privacy. Machine creativity and machine intelligence.

314 Introduction to Computer Systems and Organization Fall or spring. 4 credits. Prerequisite: Computer Science 211 or equivalent.
2 lecs, 1 lab.
Logical structure of digital computers: representation of information, addressing mechanisms, storage and peripheral hardware, the input-output channel.

321 Numerical Methods Fall or spring. 4 credits. Prerequisites: Mathematics 221 or 293, and knowledge of FORTRAN equivalent to what is taught in Computer Science 100.
3 lecs.
Students solve representative problems by programming appropriate algorithms and using library programs. Numerical methods for systems of linear equations, interpolation, integration, ordinary differential equations, nonlinear equations, optimization, and linear least squares.

410 Data Structures Fall. 4 credits. Prerequisite or corequisite: Computer Science 314.
2 lecs.
Lists, trees, graphs, arrays, and other forms of data structure and their implementation. Relation between language and data structure (e.g., introduction to LISP). Dynamic storage allocation and memory management. Searching and sorting methods.

414 Systems Programming and Operating Systems Spring. 4 credits. Prerequisite: Computer Science 314 or permission of instructor.
3 lecs.
The logical design of systems programs with emphasis on multiprogrammed operating systems. Input-output methods, process synchronization, memory management, sharing, file systems. Case studies. Project to implement a small system.

417–418 Interactive Computer Graphics (also Architecture 334) 417, fall; 418, spring. 4 credits each term. Enrollment limited for 1980–81. Prerequisite: Computer Science 314.
2 lecs, 1 lab.
Introduction to the software and hardware concepts of interactive computer graphics. Topics include input methods, graphic data structures, geometric modeling, surface description methods, hidden-line/hidden-surface algorithms, image processing, color perception, and realistic image synthesis. Examples of computer-aided design applications will be presented. Assignments will consist of hands-on experience on storage tube, vector refresh, and color raster displays.

432 Introduction to Simulation and Database Systems (also OR&IE 383) Spring. 4 credits. Prerequisite: Computer Science 211. Students who want to take only the second half of this course should register in Computer Science 434.
2 lecs, 1 rec.
First half of course is concerned with discrete-event simulation: problems of modeling, programming, and experimental investigation. Balance of course is introduction to modern database systems: basic models of file organization and access strategies, and problems of file maintenance and information retrieval. Both sections involve substantial programming exercises.

434 Introduction to Database Systems Spring. 2 credits. Prerequisite: Computer Science 211 or equivalent, weeks 7–14 only. Students who want to take only the database portion of Computer Science 432 register in Computer Science 434.
2 lecs, 1 rec.
For course description, see above.

481–482 Introduction to Theory of Computing I and II 481, fall; 482, spring. 4 credits each term. Prerequisites: Computer Science 211 and 280 or equivalent mathematics, or permission of instructor.
3 lecs.
Introduction to modern theory of computing. Covers automata theory, formal languages, effective computability, computational complexity, analysis of algorithms.

490 Independent Reading and Research Fall or spring. 1–4 credits.
Independent reading and research for undergraduates.

600 Computer Science and Programming Fall. 1 credit. Prerequisite: graduate standing in computer science or permission of instructor.
Introduction to practical, modern ideas in programming methodology. Covers style and organization of programs, basic techinques for presenting proofs of correctness of programs, the use of a "calculus" for the derivation of programs.

611 Advanced Programming Languages Fall. 4 credits. Prerequisite: Computer Science 410 or equivalent.
3 lecs.
Formal specification of programming languages, including LISP, ALGOL 60, and PL/I. Principles of structure and design and recent developments in programming languages, including ALGOL 68. Introduction to program schemata and semantics and their application in classifying and comparing programming languages.

612 Translator Writing Spring. 4 credits. Prerequisite: Computer Science 410 and 481 or permission of instructor.
3 lecs.
Discussion of the models and techniques used in the design and implementation of compilers. Topics include lexical analysis in translators, compilation of arithmetic expressions and simple statements, specifications of syntax, algorithms for syntactic analysis, code generation and optimization techniques, bootstrapping methods, translator writing systems.

613 Concurrent Programming and Operating Systems Principles Fall. 4 credits. Prerequisites: Computer Science 410 and 414 or permission of instructor.
3 lecs.
Advanced techniques and models of concurrent systems. Synchronization of concurrent processes. Parallel programming languages. Deadlock. Verification.

[615 Machine Organization Spring. 4 credits. Prerequisite: Computer Science 314 or permission of instructor. Not offered 1980–81.]
3 lecs.

[618 Picture Processing Spring. 4 credits. Prerequisite: Computer Science 611 or permission of instructor. Not offered 1980–81.]
3 lecs.

621–622 Numerical Analysis 621, fall; 622, spring. 4 credits each term. Prerequisites: a course in mathematics beyond freshman-sophomore calculus, such as Mathematics 411, 421, or 431; working knowledge of FORTRAN.
3 lecs.
The analysis and implementation of algorithms for the numerical solution of basic mathematical problems. Emphasis is placed on the estimation of error, the analysis of stability, and how to design efficient and reliable numerical algorithms. During both terms the student solves representation problems by writing original programs and by making use of high quality, state-of-the-art software. Fall term: direct methods for linear equations, interpolation, least squares and polynomial approximation, nonlinear equations, and optimization. Spring term: Quadrature, ordinary and partial differential equations, methods for sparse systems of linear equations, eigenvalue problems.

623 Short Course on Linear and Nonlinear Least Squares 2 credits. Fall, weeks 1–6 only. Prerequisite: knowledge of Computer Science 321 or permission of instructor.
Topics include: orthogonal matrix methods for the least squares (LS) problem, using LINPACK to solve the LS problem, the Lawson-Hanson codes, variable projection methods for fitting sums of exponentials, and software for general nonlinear least squares problems.

624 Short Course on Spline Approximation 2 credits. Fall, weeks 7–12 only. Prerequisite: knowledge of Computer Science 321 or permission of instructor.
Practical introduction to curve and surface fitting with splines. Topics include: interpolation with cubic splines, parabolic spline interpolation, B-splines, smoothing, and splines under tension. The deBoor spline package is extensively used.

632 Data Base Systems Fall. 4 credits. Prerequisites: Computer Science 410, and either 432 or permission of instructor.
2 lecs.
Review of hierarchical network and relational data base models. Principal data base systems and query languages. Hardware for data base processing. Implementation and optimization questions. Data integrity and protection for distributed systems. Relational data base theory.

635 Information Organization and Retrieval Spring. 4 credits. Prerequisite: Computer Science 410 or equivalent.
2 lecs.
Introduction to information retrieval. File organization and search algorithms. Statistical analysis and automatic classification of information. Structural language analysis. Dictionary techniques. Interactive retrieval. Questioning and answering and database retrieval. Evaluation of retrieval effectiveness.

681 Theory of Algorithms and Computing I Fall. 4 credits. Prerequisite: Computer Science 482 or permission of instructor.
3 lecs.
Computational models, measures of complexity, analysis of algorithms, arithmetic complexity, lower bounds, reducibilities, polynomial complete problems.

682 Theory of Algorithms and Computing II Spring. 4 credits. Prerequisite: Computer Science 481 or permission of instructor.
3 lecs.

Advanced treatment of theory of computation, computational complexity theory, and other topics in computing theory.

709 Computer Science Graduate Seminar Fall or spring. 1 credit. For graduate students interested in computer science.
1 sem. Staff, visitors, and students.
A weekly meeting for the discussion and study of important topics in the field.

711 Theory of Programming Languages Spring. 4 credits. Prerequisites: Computer Science 611 and 481. Offered alternate years.
2 lecs.
Advanced topics in formal semantics. Topics may include mathematical semantics, program verification systems, application of formal semantics to language design, variable-free languages, correctness of implementations.

[712 Theoretical Aspects of Compiler Construction Spring. 4 credits. Prerequisites: Computer Science 612 and 481. Offered alternate years. Not offered 1980–81.
2 lecs.
Formal methods of syntactic analysis, including precedence, bounded context, and LR techniques. General parsing methods and their time-spaced complexity. Noncanonical parsing techniques. Formal methods of object code optimization.]

713 Seminar in Operating Systems Fall or spring. 4 credits. Prerequisite: Computer Science 613 or permission of instructor.
1 sem.
Discussion of contemporary issues in operating systems.

719 Seminar in Programming Fall or spring. 4 credits. Prerequisite: Computer Science 611 or permission of instructor.
1 sem.

721 Advanced Numerical Analysis Fall. 4 credits. Prerequisite: Computer Science 621 or 622 or permission of instructor. Alternates with Computer Science 722.
Topics are chosen at instructor's discretion. Sample topics include matrix computations, numerical optimization, numerical solution of ordinary differential equations and integral equations, and numerical approximation.

722 Advanced Numerical Analysis Spring. 4 credits. Alternates with Computer Science 721. See 721 description, above.

[723 Numerical Solution of Ordinary Differential Equations and Integral Equations Fall. 4 credits. Prerequisite: Computer Science 622 or permission of instructor. Not offered 1980–81.]

[725 Numerical Solution of Partial Differential Equations Spring. 4 credits. Prerequisite: Computer Science 622 or permission of instructor. Not offered 1980–81.
Hours to be arranged.
General classification, solution by method of characteristics, finite-difference methods for hyperbolic and elliptic equations, parabolic equations in two dimensions, direct solution of elliptic finite-difference equations, iterative methods for the solution of elliptic equations, block methods for large systems, singularities in elliptic equations, stability in relation to initial value problems, and nonlinear discretization algorithms.]

727 Matrix Computations Fall. 4 credits. Prerequisite: Computer Science 621 or permission of instructor.
Algorithms for special linear systems, least squares, and generalized eigenvalue problems. Iterative and Lanczos techniques for sparse versions of these problems. Applications in statistics and control theory are discussed.

729 Seminar in Numerical Analysis Fall or spring. 4 credits. Prerequisite: permission of instructor.

[733 Selected Topics in Information Processing (also OR&IE 789) Not offered 1980–81.]

734 Seminar in File Processing Fall. Credit and hours to be arranged. Prerequisite: Computer Science 733.

739 Seminar in Information Organization and Retrieval Fall or spring. 4 credits. Prerequisite: Computer Science 635.

[781 Advanced Theory of Computing Fall. 4 credits. Prerequisites: Computer Science 681 and 682, or permission of instructor. Alternates with Computer Science 782. Not offered 1980–81.
At instructor's discretion, advanced topics, possibly including automata, computability, computational complexity, program schemata, semantics, and analysis of algorithms.]

782 Advanced Theory of Computing Spring. 4 credits. Alternates with Computer Science 781.

789 Seminar in Automata Theory Fall or spring. 4 credits. Prerequisite: permission of instructor.
1 sem.

790 Special Investigations in Computer Science Fall or spring. Prerequisite: permission of a computer science adviser.
Independent research.

890 Special Investigations in Computer Science Fall or spring. Prerequisite: permission of a computer science adviser.
Master's degree research.

990 Special Investigations in Computer Science Fall or spring. Prerequisite: permission of a computer science adviser.
Doctoral research.

Electrical Engineering

210 Introduction to Electrical Systems Fall or spring. 3 credits. Prerequisites: Mathematics 192 and Physics 112.
3 lec-recs.
Circuit elements and laws; natural response of linear systems; impedance and pole-zero concepts; complex frequency and phasors; forced response and power systems; transfer function and frequency response; low-frequency terminal characteristics of diodes, triodes, and transistors; linear models of electronic devices; bias circuits and frequency response of amplifiers; operational amplifiers, feedback, and oscillators.

230 Introduction to Digital Systems Fall or spring. 3 credits.
2 lecs, 5 lab experiments.
Introduction to basic analysis and design techniques and methodology of digital and computer systems. Boolean algebra; integrated circuit components used in digital system implementation; codes and number systems; logic design of combinational circuits; logic design of sequential circuits.

301 Electrical Signals and Systems I Fall. 4 credits. Prerequisites: Electrical Engineering 210 and Mathematics 294 or equivalents.
3 lecs, 1 rec-computing session.
Formulation of circuit equations, steady-state response. Laplace transform and applications. System functions. State description of linear systems. Natural modes, initial conditions, forced response. Two-port circuit descriptions. Models for active circuits.

302 Electrical Signals and Systems II Spring. 4 credits. Prerequisite: Electrical Engineering 301.
3 lecs, 1 rec-computing session.
Single-sided and bilateral Laplace transforms. Applications of complex functions and contour integration to system response. Stability criteria. Transmission line transients. Fourier series and integrals. Discrete and Fast Fourier transforms. Sampling.

303 Electromagnetic Theory I Fall. 4 credits. Prerequisites: Physics 214 and Mathematics 294.
3 lecs, 1 rec-computing session.
Foundation of electromagnetic theory. Topics include Maxwell's equations; boundary conditions and the Laplace equation; plane waves, wave propagation and reflection at boundaries, the Poynting theorem; guided TEM, TM, and TE waves, impedance transformation, and matching. Introduction to simple antenna systems.

304 Electromagnetic Theory II Spring. 4 credits. Prerequisites: Electrical Engineering 301 and 303.
3 lecs, 1 rec-computing session.
Fundamentals of electromagnetic theory with emphasis on wave propagation and guidance, radiating systems, and the effects of the medium on transmission. Topics include retarded potentials; relation of radiation fields to source distributions, antenna gain concepts and techniques in antenna design; wave guide systems, separation of variables, cavities, and losses; propagation in inhomogeneous and anisotropic media, complex permittivity, plasma and magnetic field effects.

306 Fundamentals of Quantum and Solid-State Electronics Spring. 4 credits. Prerequisites: Physics 241, Mathematics 294, and coregistration in 303.
3 lecs, 1 rec-computing session.
Introductory quantum mechanics and solid-state physics necessary for understanding lasers and modern solid-state electronic devices. Quantum mechanics is presented in terms of wave functions, operators, and solutions of Schroedinger's equation. Topics include the formalism and methods of quantum mechanics, the hydrogen atom, the structure of simple solids, energy bands, Fermi-Dirac statistics, and the basic physics of semiconductors. Applications studied include a simple metal, thermionic emission and the p-n junction.

310 Probability and Random Signals Spring. 4 credits.
3 lecs, 1 rec-computing session.
Introduction to modeling random phenomena and signals and applications of these models. Topics include: concepts of probability, conditional probability, independence, random variables, expectation and random processes. Applications to problems of inference, estimation, and linear system response in communications, computers, control, and pattern classification.

315 Electrical Laboratory I Fall. 4 credits. Prerequisites: Electrical Engineering 210 and coregistration 301.
2 lecs, 2 labs.
Basic electrical and electronic instrumentation and measurements involving circuits and fields of both active and passive elements; an experimental introduction to solid-state theory and devices.

316 Electrical Laboratory II Spring. 4 credits. Prerequisites: Electrical Engineering 303 and 315.
2 lecs, 2 labs.
Laboratory studies of solid-state phenomena and devices; experiments illustrating the use of the digital computer in electrical engineering; laboratory studies of high-frequency phenomena and devices; and introduction to ac and dc machinery.

407 Quantum Mechanics and Applications Fall. 4 credits. Prerequisite: Electrical Engineering 306.
3 lecs, 1 rec-computing session. R. Liboff.
Review of basic classical and quantum mechanical relations. Harmonic oscillator. Annihilation and creation operation. WKB technique. Superposition principle. Addition of angular momentum. Ladder operators. Clebsch-Gordon coefficients. Radiation from an atom. Selection rules. Pauli principle. Spin-orbit coupling. Spin states. Helium atom and hydrogen molecule. Magnetic resonance. Perturbation theory. The born approximation. Nearly-free-electron model. Planck radiation law.

430 Introduction to Lasers and Optical Electronics Spring. 4 credits. Prerequisite: Electrical Engineering 306 or equivalent (such as Physics 443).
2 lecs, 1 lec-rec, 1 lab.
An introduction to stimulated emission devices such as masers, lasers, and optical devices based on linear and nonlinear responses to coherent fields. Material discussed, based on quantum mechanical results, employs phenomenological theories and stresses applications to modern devices. Discussions of applications include the operating principles of a variety of important lasers, crystal optics with application to electro-optic and acousto-optic modulators, and an introduction to integrated optics. Labs present an opportunity to work with a variety of the lasers and processes discussed in lectures.

480 Thermal and Statistical Physics for Engineers Spring 3 credits. Prerequisite: Physics 214.
R. Liboff.
Thermodynamic principles. Elementary theory of transport coefficients. Central-limit theorem, Random walk. Electrical noise. Quantum and classical statistics. Black body radiation. Thermal properties of solids. Elementary descriptions of the p-n junction, shock waves, superfluidity, superconductivity, and the laser.

531–532 Electronic Circuit Design 531, fall; 532, spring. Fall, 4 credits; spring, 3 or 4 credits. Prerequisites: Electrical Engineering 230 and 316.
3 lecs, 1 optional lab. N. H. Bryant.
Design techniques for circuits used in electronic instrumentation. A variety of circuits that employ discrete components, operational amplifiers, I-C timers, and logic circuitry are considered. Emphasis is placed on designing for specified function rather than on detailed analyses. At the level of *Electronics for Scientists* by Malmstadt et al.

591–592 Senior Project 591, fall; 592, spring. 3 credits.
Individual study, analysis, and, usually, experimental tests in connection with a special engineering problem chosen by the student after consultation with the faculty member directing the project. An engineering report on the project is required.

621 Bioinstrumentation Fall. 3 credits (4 credits with lab). Prerequisites: Electrical Engineering 301 and 316.
3 lecs, 1 lab. W. J. Heetderks.
The acquisition and processing of biological signals. Topics include electrodes, ion selective electrodes, temperature transducers, pressure transducers, flow transducers, force transducers, displacement transducers, operational amplifiers, instrumentation amplifiers, analog signal processing, D/A and A/D conversion, and digital processing with minicomputers and microprocessors.

622 Neuroelectric Systems (also Biological Sciences 696) Spring. 3 (4 credits with lab). Prerequisite: either Electrical Engineering 301 or 621, or Biological Sciences 423 or 496; written permission of instructor required for lab. Offered alternate years.
Disc and demonstration to be arranged; lab to be arranged. M. Kim, R. Capranica.
Application of microprocessors for neuroelectric data acquisition and systems analysis. Lectures will cover electrical activity of single nerve cells, electrodes and instrumentation techniques, analysis of electrophysiological data, and coding principles in the nervous system, as well as appropriate background material for the use of microprocessors in neurobiology. Laboratory exercises will provide experience in the actual use of microprocessors.

623 Active and Digital Network Design Fall. 3 credits (4 credits with lab). Prerequisite: Electrical Engineering 301.
3 lecs, 1 lab. W. H. Ku.
Design of passive filters and matching networks. Active filter design using operational amplifiers. Design of transistor amplifiers. Digital signal processing. Z-transform and discrete Fourier transform (DFT). Design of nonrecursive and recursive digital filters. Fast Fourier transform (FFT) algorithms.

624 Computer Methods in Electrical Engineering Spring. 4 credits. Prerequisite: Electrical Engineering 301.
Modern techniques for solving electrical engineering problems on the digital computer. Emphasis on efficiency and numerical stability rather than on theoretical implications. Solution of linear and nonlinear algebraic equations; integration; solution of ordinary differential equations; random number generators. Applications to power systems, control systems, communication systems, and circuit design.

626 Advanced Digital Signal Processing Spring. 3 credits (4 credits with lab). Prerequisites: Electrical Engineering 623 or permission of instructor.
3 lecs, 1 lab.
Topics include FIR and IIR filter design; the DFT, FFT, and CZT; spectral analysis; data compression; adaptive filters, and speech synthesis. Laboratory involves design of filters using minicomputer-based design tools and implementation of real-time digital filters with microprocessor-based filter systems. At the level of Rabiner and Gold, *Theory and Application of Digital Signal Processing*.

627 Fundamentals of Linear Networks Fall. 4 credits. Prerequisite: Electrical Engineering 302.
3 lecs.
Scattering and generalized network formalisms with applications. Nonreciprocal and active network properties. Applications of Tellegen's theorem. Passive and active network invariants applied to gain and stability problems.

628 Network Theory and Applications Spring. 4 credits. Prerequisite: Electrical Engineering 302.
3 lecs.
Circuit properties in complex frequency domain. Realizability theory. Insertion loss design of lumped and microwave filters, equalizers, and linear phase structures. Gain bandwidth theory for broadband matching and wideband amplifiers.

630 Physical Electronics of Solids Fall. 4 credits. Prerequisites: Electrical Engineering 306 and 304 or 407 or permission of instructor.
3 lecs, 1 rec.
Topics include crystal symmetry and effects on device processing and operation; lattice vibrations; energy bands and their effects on device design and operation; hot-electron effects; transport of electrons and holes; optical properties; magnetic properties. These topics are discussed in terms of their influence on the operation of solar cells, photocathodes, microwave semiconductor devices, junction lasers and LEDs, and bubble and charge-control memories.

631–632 Semiconductor Electronics I and II 631, fall; 4 credits. 632, spring; 3 credits. Prerequisites: Electrical Engineering 306 and 316.
631: 3 lecs, 1 lab. 632: 3 lecs.
Properties of semiconductors, theory of P-N junction, practical P-N diodes, metal-semiconductor contacts, diode switching, characteristics and application of bipolar junction transistors, circuit models for BJT's, MOS and junction field-effect transistors, four-layer devices and applications. At the level of *Electronic Circuits* by Holt.

633 Solid-State Microwave Devices and Subsystems I Fall. 3 credits.
Prerequisite: Electrical Engineering 304.
2 lecs, 1 lab.
Theoretical and experimental studies of circuits, amplifiers, oscillators, detectors, receivers, and electrical noise at microwave frequencies. Typical topics: one- and two-port resonators; negative resistance amplifiers; oscillator load characteristics, locking and stabilization; microwave transistor amplifiers; intermodulation effects; resistor and shot noise; noise temperature, fm noise.

634 Solid-State Microwave Devices and Subsystems II Spring. 3 credits. Prerequisite: Electrical Engineering 633.
2 lecs, 1 lab.
Basic theories of solid-state devices at microwave frequencies. Specific devices studied: varactors, avalanche diodes; transferred electron diodes; pnp oscillator diodes; tunnel diodes; pin diodes; and microwave transistors. Studies of experimental methods of characterizing these devices include use of H.P. network analyzer and other microwave equipment.

636 Integrated Circuit Technology Spring. 3 credits. Prerequisite: 631 or permission of instructor.
2 lecs, 1 lab.
Integrated circuit fabrication techniques applicable in the fields of computer hardware, telecommunication systems, and optoelectronics, with emphasis on device technology. Diffusion, oxidation, ion implantation; limits on device performance and device design, both MOS and bipolar. Compound semiconductors. At the level of current papers in *IEEE Transactions on Electron Devices*.

651–652 Electric Energy Systems I and II 651, fall; 652, spring. 4 credits each term. Prerequisite for 651: Electrical Engineering 316 or permission of instructor.
3 lec-recs, 1 lab-computing session. S. Linke.
Engineering principles underlying operation of modern electric power systems under steady-state and transient conditions emphasizing major power-system parameters. Digital computer used as dynamic "laboratory" model of complex power systems for load-flow, fault, stability, and economic-dispatch studies. At the level of *Elements of Power System Analysis* (Third ed.) by Stevenson.

655 Advanced Power Systems Analysis I Fall. 3 credits. Prerequisite: Electrical Engineering 302 and concurrent registration in 651, or permission of instructor.
R. J. Thomas, S. Linke.
Analysis of power-system components. These components include rotating machines and systems for excitation control, automatic voltage regulation, boiler-turbine control, and speed regulation as well as ancillary three-phase networks. Emphasis on derivation of mathematical models from first principles; development of algorithms for the formation of applicable network matrices.

656 Advanced Power Systems Analysis II Spring. 3 credits. Prerequisites: Electrical Engineering 655 and concurrent registration in 652 or permission of instructor.
J. S. Thorp, C. Pottle.
Computer methods in power systems applied to short-circuit studies, load-flow studies, transient-stability studies, economic dispatch, and security load flows. Use of sparse-matrix techniques. Comparison of algorithms for digital relaying. State-estimation algorithms. Emphasis on the use of the digital computer in the planning and operation of

large-scale power systems. At the level of *Computer Methods in Power System Analysis* by Stagg and El-Abiad.

661 Error Control Codes Fall. 3 or 4 credits (4 with lab). Lab prerequisite: FORTRAN or PL/I.
3 lecs, 1 lab.
Development of codes for correction or detection of errors in digital data transmission, encoding and decoding algorithms and their implementation using feedback shift register circuits or computer programs. The underlying algebraic theory (groups, Galois fields) is developed from the beginning as needed. The codes studied include Hamming codes, cyclic codes, BCH codes, Reed-Solomon codes, convolutional tree codes, and burst-correcting codes. Lab consists of computer implementation of algorithms covered in lecture.

662 Fundamental Information Theory Spring. 3 or 4 credits (4 with lab). Prerequisite: Electrical Engineering 310 or equivalent. Prerequisite for lab only: Electrical Engineering 661 with lab.
3 lecs, 1 lab.
Fundamental results of information theory with application to storage, compression, and transmission of data. Entropy and other information measures. Block and variable-length codes. Channel capacity and rate-distortion functions. Coding theorems and converses for classical and multiterminal configurations. Gaussian sources and channels. Lab projects investigate problems of statistical characterization of sources and channels using computer simulation.

664 Decision Making and Estimation Fall. 4 credits. Prerequisite: Electrical Engineering 310 or equivalent.
Bayes, minimax, and Neyman-Pearson decision theories, including asymptotic error rates. Bayes and maximum likelihood estimation. Cramer-Rao bound, Fisher information, efficient and consistent estimates. Coherent signal-processing applied to estimation and decision-theory problems in radar, sonar and surveillance. Estimation of range, doppler, spectral moments. Ambiguity functions, synthetic aperture imaging.

667 Communication Systems I Fall. 4 credits. Prerequisite: Electrical Engineering 310 or equivalent.
2 lecs, 1 rec.
Analog and digital signal representation, spectral analysis, linear signal processing, modulation and demodulation systems. Time and frequency division multiplex systems. Introduction to random processes and noise in analog and digital systems.

668 Communication Systems II Spring. 4 credits. Prerequisite: Electrical Engineering 667 or equivalent.
3 lecs, 1 rec.
Analysis of multiterminal communication systems. Basic results on Markov chains and queueing theory will be covered. Satellite communication systems and ground networks will be investigated: stability properties, measures of performance, optimization of such systems.

671–672 Feedback Control Systems 671, fall; 672, spring. 3 credits each term (4 with lab). Prerequisite: Electrical Engineering 302 or permission of instructor.
System performance specifications. Analysis of linear feedback control systems by root locus and frequency response methods. Classical cascade and feedback compensation techniques. Sampled-data systems and digital compensation. Laboratory work consists of familiarization with system frequency response measurements, transfer function measurements, and transient response measurements; also, design and compensation of linear positional and speed control systems, analysis and compensation of sampled-data systems. Emphasis is on correlation of theoretical and experimental results.

675 Computer Structures Fall. 4 credits. Prerequisite: Electrical Engineering 230 or Computer Science 314.
3 lecs, 1 lab. N. M. Vrana.
Organization and design of digital computers, arithmetic hardware, I/O systems. Three laboratory groups combine efforts to design and build a digital computer.

676 Microprocessor Systems Spring. 4 credits. Prerequisite: Electrical Engineering 675.
3 lecs, 1 lab. N. M. Vrana.
System design using microprocessors. Hardware and software techniques employed for logic design, interfacing, instrumentation, and control.

677 Computer Processor Organization and Memory Hierarchy Fall. 4 credits. Prerequisites: Electrical Engineering 676 and 310, or permission of instructor.
Design and evaluation of processor and memory architectures is examined in light of actual implementations of both large-scale and small-scale (microprocessors) systems. Topics include: microprogramming and directly executable languages, number representation and instruction set trade-offs, parallel and pipelined architectures, interleaved memories, cache and virtual memories, multilevel memory hierarchies, and protection mechanisms.

678 Computer Input/Output and Distributed Architecture Spring. 4 credits. Prerequisite: Electrical Engineering 677 or permission of instructor.
Methods and approaches to input/output processing, device interface, selector and multiplexor channels, parallel processing, task partitions and resource allocations, distributed processing, interconnection topology, minicomputer and microcomputer networks, interprocessor communications.

679 Current Topics in Computer Engineering Fall. 3 credits. Prerequisite: Electrical Engineering 677 or coregistration in 677.
2 lecs.
In-depth treatment of current and emerging computer engineering research and development activities. Topics vary from year to year and are chosen from research reports and published journal articles. Subjects may include: fault tolerant computing, reliability studies, innovative microcomputer structures, direct execution of high-level languages, and impact of very-large-scale integration technologies on computer organizations.

[680 Elementary Plasma Physics and Gas Discharges Fall. 3 credits. Prerequisite: Electrical Engineering 304 or equivalent. Not offered 1980–81.
2 lecs, 1 lab.
Coordinated lectures and ten experiments. Discharges, arcs, reflex discharge. Positive column, collisions, diffusion, breakdown, sheaths. Langmuir probes. Electromagnetic waves, plasma oscillations, space-charge waves, cyclotron harmonic radiation. Microwave and laser interferometers. Relativistic electron beams.]

681 Introduction to Plasma Physics (also A&EP 606) Fall. 4 credits. Prerequisites: Electrical Engineering 303 and 304 or equivalent. First-year graduate-level course; open also to *exceptional* fourth-year students at discretion of instructor.
3 lecs.
Plasma state; motion of charged particles in fields; collisions, coulomb scattering; transport coefficients, ambipolar diffusion, plasma oscillations and waves; hydromagnetic equations; hydromagnetic stability and microscopic instabilities; test particle in a plasma; elementary applications.

682 Advanced Plasma Physics (also A&EP 607) Spring. 4 credits. Prerequisite: Electrical Engineering 681.
3 lecs.
Boltzmann and Vlasov equations; waves in hot plasmas; Landau damping, microinstabilities; drift waves, low-frequency stability, collisional effects; method of dressed test particles, high-frequency conductivity and fluctuations; neoclassical toroidal diffusion, high powered beams.

683 Electrodynamics Fall. 4 credits. Prerequisite: Electrical Engineering 304 or equivalent.
3 lecs.
Maxwell's equations, electromagnetic potentials, integral representations of the electromagnetic field. Special theory of relativity. Radiation of accelerated charges. Cerenkov radiation. Optional topics: electrodynamics of dispersive dielectric and magnetic media; elementary quantum electrodynamics, second quantization, interaction of electromagnetic fields with atoms. At the level of *Classical Electrodynamics* by Jackson.

684 Microwave Theory Spring. 4 credits. Prerequisite: Electrical Engineering 304 or equivalent.
3 lecs. P. McIsaac.
Theory of passive microwave devices. Homogeneous and inhomogeneous waveguides. Nonreciprocal waveguide devices. Scattering matrix analysis of multiport junctions, resonant cavities, directional couplers, isolators, circulators. Periodic waveguides, coupled mode theory. At the level of *Introduction to the Theory of Microwave Circuits* by Kurokawa.

[685–686 Upper Atmosphere Physics I and II 685, fall; 686, spring. 3 credits each term. Not offered 1980–81.
3 lecs.
Physical processes in the earth's ionosphere and magnetosphere, the solar corona, and the solar wind. Diagnostic techniques including radar and in situ observations; production, loss, and transport of charged particles in the ionosphere and magnetosphere; airglow; tides, winds, and gravity waves; electric fields generated by the solar wind and winds in the neutral atmosphere and their effects on transport processes; the equatorial and auroral electrojets; instabilities in space plasmas, structure of the solar corona and solar wind and their interaction with the magnetosphere; acceleration and drift of energetic particles in the magnetosphere; precipitation of particles and the aurora; magnetic and ionospheric storms.]

687 Electromagnetic Wave Propagation I Fall. 3 credits.
3 lecs.
Some aspects of antenna theory; diffraction; refraction and ducting in the troposphere; propagation of radiowaves and cold plasma waves in the ionosphere and magnetosphere; Alfven, whistler mode, and hybrid waves; the CMA diagram; WKB solutions of the coupled wave equations.

688 Electromagnetic Wave Propagation II Spring. 3 credits.
3 lecs.
Full-wave solutions of the wave equations; interactions between particles and waves; scattering of radio waves from random fluctuations in refractive index; scatter progagation; incoherent scatter from the ionosphere and its use as a diagnostic tool; radio star and satellite scintillations and their use as diagnostic tools; radar astronomy.

690 Fundamentals of Acoustics (also T&AM 666) Spring. 3 credits.
3 lecs, biweekly lab.
See T&AM 666 for course description.

691–699 Special Topics in Electrical Engineering 1–3 credits.
Seminar, reading course, or other special arrangement agreed upon between the students and faculty members concerned.

721 Theory of Linear Systems Fall. 4 credits. Prerequisite: Electrical Engineering 302 or permission of instructor.
The state-space model for linear systems. Fundamental and transition matrices. Matrix exponential functions, the Cayley-Hamilton theorem, and the Jordan form. Forced network and system response. Controllability, observability, stability, realizability. Applications of Fourier, Laplace, Hilbert transforms. Paley-Wiener theorem. At the level of *System Theory* by Padulo and Arbib.

[722 Theory of Nonlinear Systems Spring. 4 credits. Prerequisite: Electrical Engineering 721. Not offered 1980–81.
3 lecs.
Analysis of nonlinear systems with applications. Phase-plane analysis; singular points, limit cycles, and equilibrium states. Stability of nonlinear systems; the methods of Lyapunov and Popov; circle criteria. Forced nonlinear systems; periodic systems. Floquet theory, Mathieu-Hill theory; applications to the stability of nonlinear and parametrically excited systems.]

731 Quantum Electronics I Fall. 4 credits. Prerequisites: Electrical Engineering 306 and 407 or Physics 443.
3 lecs, 1 rec-computing session.
A detailed treatment of the physical principles underlying lasers and masers, related fields, and applications. Topics include: a review of quantum mechanics and the quantum theory of angular momentum, the interaction of radiation and matter, including emission, absorption, and scattering; the quantum mechanical density matrix and macroscopic material properties; theory of the laser, including methods of achieving total and partial population inversion; Lamb theory.

732 Quantum Electronics II Spring. 4 credits. Prerequisite: Electrical Engineering 731 or permission of instructor.
3 lecs, 1 rec-computing session.
A continuation of 731. Topics include: optical resonators, output power of amplifiers and oscillators; dispersive effects and laser oscillation spectrum. Spectroscopy of atoms, molecules, and ions in crystals as examples of laser media; survey of chemical and dye lasers; noise in optical devices; principles of electro-optic and parametric devices.

733 Opto-Electronic Devices Fall. 4 credits. Prerequisites: Electrical Engineering 304 and 630 or equivalent.
3 lecs, 1 rec.
An understanding of physical properties of solids that affect use in optical devices is sought. Wave propagation in lossy, anisotropic, layered, and electro-optic media; microscopic and band-theoretic models for dielectric constant and loss; carrier transport, scattering and trapping; photoconductivity; electro-optics, photoemissive and photoconductive devices; noise in optical detectors.

734 Theory and Applications of Nonlinear Optics 4 credits. Prerequisite: Electrical Engineering 731 or 733 or equivalent of Physics 572.
3 lecs, 1 rec.
Basic concepts and recent developments in nonlinear and electro-optics. Topics will include higher-order perturbation theory of the Schroedinger and density-matrix equations and their applications in nonlinear optics; classical anharmonic oscillators; nonlinear optical properties of organic and inorganic crystals and semiconductors; harmonic generation and multiphoton processes; nonlinear and electro-optical devices and their applications in, for example, spectroscopy and optical communications. At the level of Rabin and Tang and current literature.

735 Solid-State Devices I Fall. 4 credits. Prerequisite: Electrical Engineering 630 or equivalent.
3 lecs.
Band structure, generation recombination statistics, ambipolar transport, deep level spectroscopy, p-n junction analysis, contact technology, secondary ionization, and noise. A review of ion implantation technology with emphasis on associated material and device problems. Topics are presented on the level of current device research literature. Presentation concentrates on relating basic material properties to device parameters. Term paper.

736 Solid-State Devices II Spring. 4 credits. Prerequisite: Electrical Engineering 735 or equivalent.
3 lecs.
A general treatment of the time dependence of secondary ionization and the simpler "quasistatic" approximation. Applications to microwave generation and amplification and broadband optical detection, including stability, nonlinearity, and noise. The fundamentals of transferred electron devices, including band structure, distribution functions, stability and doping configurations of devices. Term paper.

[737 Physics, and Technology of Very-Large-Scale Integration (VLSI) Fall. 3 credits. Prerequisites: Electrical Engineering 631–632. Not offered 1980–81.
No lab.
Basic materials and technology problems to be considered in the design and fabrication of VLSI circuits. The material problems include: reduction of threshold voltage in submicron-channel MOSFET's; hot-electron tunneling through MOSFET oxides; mobility reductions in thin expitaxial layers; role of velocity overshoot effects in short-channel devices; comparison of elemental and compound semiconductors. Technology problems include: fabrication methods for submicron dimensions; light-sensitive, electron-beam, and x-ray resists; testing of VLSI circuits; throughput; yield.]

738 Physics of Solid-State Devices Spring. 2–3 credits. Prerequisite: Electrical Engineering 736 or equivalent.
2 lecs.
Basic theory of electron and hole scattering in semiconductors. Examination of methods for obtaining high electric field solutions for the distribution function from the Boltzmann equation. Hot electron phenomena reviewed with emphasis on band-structure induced instabilities.

739 VLSI Digital System Design Fall. 3 credits. Prerequisites: Electrical Engineering 636 and 676.
N. R. Powell.
Theory of operation of MOS devices and circuits, and their fabrication; the foundations of LSI system design and implementation; examples of LSI system design; and topics of current research relating to system timing, arrays of extensible LSI devices, algorithms consistent with VLSI processor arrays, and organization of hierarchical and concurrent computing devices. A laboratory project is required.

[761–762 Random Processes in Electrical Systems 761, fall; 762, spring. 4 credits each term. Prerequisites: Electrical Engineering 302 and 310. Not offered 1980–81.
3 lecs.
The concepts of randomness and uncertainty and their relevance to the design and analysis of electrical systems. An axiomatic characterization of random events. Probability measures, random variables, and random vectors. Distribution functions and densities. Functions of random vectors. Expectation and measures of fluctuation. Moments and probability inequalities. Properties and applications of characteristic functions. Modes of convergence of sequences of random variables: laws of large numbers and central limit theorems. Kolmogorov consistency conditions for random processes. Poisson process and generalizations. Gaussian processes. Covariance stationary process, correlation function, spectra; Bochner and Wiener-Khinchin theorems. Continuity, integration, and differentiation of sample functions. Optimum filtering and prediction. Spectral representation, orthogonal series representations. Markov chains and processes. Linear and nonlinear transformations of random processes.]

[763 Advanced Topics in Information Theory Fall. 4 credits. Prerequisites: Electrical Engineering 662 and either 761 or Mathematics 571 or permission of instructor. Not offered 1980–81.
3 lecs.
An in-depth treatment of an information theory research area. The topic varies from year to year and is chosen from the following subjects: source encoding (rate-distortion theory), convolutional codes and sequential decoding, multiterminal communication networks, ergodic theory and information, and complexity and instrumentability of coding schemes.]

764 Foundations of Inference and Decision Making Spring. 3 credits. Prerequisite: a course in probability and some statistics, or permission of instructor.
3 lecs.
An examination of methods for characterizing uncertainty and chance phenomena and for transforming information into decisions and optimal systems. Discussion of the foundations of inference includes: comparative probability; quantitative probability; relative frequency interpretations; computational complexity; randomness; classical probability and invariance; induction; subjective probability.

771 Estimation and Control in Discrete Linear Systems Fall. 4 credits. Prerequisites: Electrical Engineering 302 and 310 or permission of instructor.
3 lecs.
Optimal control, filtering, and prediction for discrete time linear systems with extensive use of the APL/360 system. Approximation on discrete point sets. The principle of optimality. Kalman filtering. Stochastic optimal control.

772 Optimal Control and Estimation for Continuous Systems Spring. 4 credits. Prerequisite: Electrical Engineering 771 or permission of instructor.
3 lecs.
Control system design through parameter optimization, with and without constraints. The minimum principle; linear regulators, minimum time and minimal fuel problems. Computational techniques; properties of Lyapunov and Riccati equations.

[773 Random Processes in Control Systems Spring. 4 credits. Prerequisites: Electrical Engineering 762 and 772. Not offered 1980–81.
3 lecs.
Prediction and filtering in control systems: Gaussian-Markov process, prediction problem, stochastic optimal and adaptive control problems. Control of systems with uncertain statistical parameters; stochastic differential equations, optimal nonlinear filtering; stability of control systems with random parameters.]

781 Kinetic Theory (also A&EP 761) Fall. 3 credits. Prerequisite: Electrical Engineering 407 or Physics 561, or permission of instructor. Offered alternate years.
2 lecs. R. L. Liboff.
Theory of the Liouville equation, Prigogine and Bogoliubov analysis of the BBKGY sequence. Master equation, density matrix, Wigner distribution. Derivation of fluid dynamics. Transport coefficients. Boltzmann, Krook, Fokker-Planck, Landau, and Balescu-Lenard equations. Properties and theory of the linear Boltzmann collision operator. The relativistic Maxwellian. Klimontovich formulation. At the level of *Introduction to the Theory of Kinetic Equations* by Liboff.

791–792 Electrical Engineering Colloquium 791, fall; 792, spring. 1 credit each term. For students enrolled in the graduate Field of Electrical Engineering.
Lectures by staff, graduate students, and visiting authorities. A weekly meeting for the presentation and discussion of important current topics in the field.

793–794 Electrical Engineering Design 793, fall; 794, spring. 3 credits each term. For students enrolled in the M.Eng.(Electrical) degree program. Utilizes real engineering situations to present fundamentals of engineering design.

795–799 Special Topics in Electrical Engineering 1–3 credits.
Seminar, reading course, or other special arrangement agreed upon between the students and faculty members concerned.

Geological Sciences

Freshman and Sophomore Courses

101 Introductory Geological Sciences Fall or spring. 3 credits.
2 lecs, 1 lab; evening exams, field trips.
C. S. Hutchison, fall; J. M. Bird, spring.
Understanding the natural earth; weathering, erosion, the evolution of coast lines and river valleys, glaciation, the origins of earthquakes and mountains, the genesis of volcanoes, and the drifting of continents. Studies of ground water, mineral deposits, petroleum, and coal. Recognizing major minerals and rocks, interpretation of topographic and geologic maps.

102 Introduction to Historical Geology Spring. 3 credits. Prerequisite: Geological Sciences 101 or permission of instructor.
2 lecs, 1 lab; evening exams. J. L. Cisne.
A continuation of 101. History of the earth and life in terms of evolutionary processes. The geologic record, its formation, and interpretation of earth history. Introduction to the evolution of life and to fossils and their use in reconstructing past environments and dating rocks.

103 Earth Science Fall. 3 credits (see Geol 105, Earth Science Laboratory).
3 lecs. T. Jordan.
Physical geography, including earth and lunar orbits that determine seasons and tides. Figure and structure of the earth; climatic regions; atmospheric and oceanic circulation; erosion by rivers, glaciers, wind, and waves; climatic change.

105 Earth Science Laboratory Fall. 1 credit. To be taken concurrently with Geol 103, Earth Science.
T. Jordan.
Astronomical determination of position and seasonal events. Topographic mapping and map interpretation. Minerals and rocks, world climatic regions.

107 Frontiers of Geology I Fall. 1 credit. May be taken concurrently with or after Geological Sciences 101.
1 lec. J. L. Cisne and staff.
Lectures by members of the department on selected fundamental topics of current interest, such as continental drift and related tectonic processes, volcanoes, earthquake prediction, natural energy sources, and mineral resources.

108 Frontiers of Geology II Spring. 1 credit. May be taken concurrently with or after Geological Sciences 101 or 102.
1 lec. J. L. Cisne and staff.
Lectures by members of the department on selected fundamental topics of current interest such as plate tectonics, the evolution of mountain belts and island arcs, the deep structure of continents, ecology and evolution of fossil organisms, correlation of strata by fossils, sea-level changes, and fossil fuels.

[131 Geology and the Environment Fall. 3 credits. Field trips. Not offered 1980–81.
2 lecs, 1 lab.
The principles of geological science, with emphasis on the physical phenomena and rock properties as they influence the natural environments of man.]

262 Mineral and Energy Resources and the Environment Spring. 3 credits.
2 lecs, 3 exercises; reading assignments, term projects. A. K. Gibbs.
Occurrence, location, and scientific principles underlying the availability of mineral and energy resources of today and tomorrow. Limitations on utilization imposed by economic and environmental factors, hazards, patterns of usage, and industrial development. Relation to national and international policy and conservation.

Junior, Senior, and Graduate Courses

Of the following, the core courses Geological Sciences 325, 345, 355–356, 376, and 388 may be taken by those who have successfully completed Geological Sciences 101–102 or the equivalent, or who can demonstrate to the instructor that they have adequate preparation in mathematics, physics, chemistry, biology, or engineering.

325 Structural Geology and Sedimentation Spring. 4 credits. Prerequisite: Geological Sciences 101 or permission of instructor.
3 lecs, 1 lab. C. S. Hutchison.
Nature, origin, and recognition of geologic structures. Behavior of geologic materials. Geomechanical and tectonic principles applied to the solution of geologic problems. Introduction to the sedimentary processes and petrology of sedimentary rocks. Description, classification, provenance, transportation, depositional environment of sediments, and diagenesis of sediments.

345 Geomorphology Spring. 4 credits. Prerequisite: Geological Sciences 102 or permission of instructor. Normal fall course offered spring 1981.
2 lecs, 1 lab. A. L. Bloom.
Description and interpretation of land forms in terms of structure, process, and stage.

355 Mineralogy, Petrology and Geochemistry I Fall. 4 credits. Prerequisite: Geological Sciences 101 or permission of the instructor.
2 lecs, 2 labs; assigned problems and readings.
W. A. Bassett.
Examination of minerals by hand specimen properties and optical microscopy. Geological setting, classification, crystal structures, phase relations, chemical properties, and physical properties of minerals are studied. X-ray diffraction is introduced.

356 Mineralogy, Petrology, and Geochemistry II Spring. 4 credits.
2 lecs, 1 lab; assigned problems and readings; field trips. R. W. Kay.
Principles of phase equilibrium as applied to igneous and metamorphic systems. Description, classification, chemistry, origin, regional distribution, and dating of igneous and metamorphic rocks. Geochemical distribution of trace elements and isotopes in igneous and metamorphic systems. The petrological evolution of the planets.

376 Historical Geology and Stratigraphy Fall. 4 credits. Recommended prerequisite: Geological Sciences 102.
2 lecs, 2 labs. J. L. Cisne, S. Bachman.
Formation of sedimentary rocks. Depositional processes. Depositional environments and their recognition in the stratigraphic record. Correlation of strata in relation to time and environment. Seismic stratigraphy. Geological age determination. Reconstruction of paleogeography and interpretation of earth history from stratigraphic evidence.

388 Geophysics and Geotectonics Spring. 4 credits. Prerequisites: Mathematics 112 and Physics 208 or equivalent.
3 lecs, 1 lab. B. L. Isacks.
Global tectonics and the deep structure of the solid earth as revealed by investigations of earthquakes, earthquake waves, the earth's gravitational and magnetic fields, and heat flow.

410 Experiments and Techniques in Earth Sciences Spring. 2 credits. Prerequisites: Physics 207–208 and Mathematics 191–192 or equivalents, or permission of instructor.
S. Kaufman.
Lab and field experiments chosen in accordance with students' interests. Familiarization with instruments and techniques used in earth sciences. Independent work is stressed.

423 Petroleum Geology Fall. 3 credits. Recommended prerequisite: Geological Sciences 325.
2 lecs, 1 lab; field trip. S. B. Bachman.
Introduction to hydrocarbon exploration and development. Source rock and fluid migration studies, oil and gas entrapment, reservoir rocks. Exploration techniques including basin analysis, subsurface mapping, seismic reflection methods and processing, seismic mapping, seismic stratigraphy. Drilling techniques, well logs and their use in stratigraphic and structural interpretations, leasing and economics, career development.

[424 Tectonics of Orogenic Zones; Modern and Ancient Spring. 3 credits. Prerequisite: permission of instructors. Offered alternate years. Not offered 1980–81.
1 lec. W. B. Travers, D. E. Karig.
A comparative study of island arcs and mountain ranges.]

[428 Geomechanics Spring. 3 credits. Prerequisites: Mathematics 240 or 296; Geological Sciences 101. Not offered 1980–81.
3 lecs. D. L. Turcotte.
Use of mathematical analysis to explain such geological observations as ocean ridges — their thermal structure, elevation, heat flow, and gravity; ocean trenches — the structure and mechanics of the bending lithosphere; folding — buckling, viscous, and plastic flow; faulting — a detailed mechanical and geological study of the San Andreas fault; intrusives — geothermal power.]

431 The Earth's Crust: Structure, Composition, and Evolution Fall. 3 credits. Prerequisites: Geological Sciences 356 and 388.
3 lecs. L. D. Brown.
Structure and composition of the crust from geophysical observations, analysis of xenoliths, and extrapolation of petrological laboratory data. Radioisotopic considerations. The nature of the crust-mantle boundary. Thermal and rheological structure of the crust. Oceanic vs. continental crust. Origin and evolution of oceanic and continental crust.

432 Digital Processing and Analysis of Geophysical Data Spring. 3 credits. Prerequisites: Geological Sciences 488 and familiarity with a programming language.
3 lecs. L. D. Brown, S. Kaufman.
Sampling theory. Fourier, Laplace, and Z-transform techniques. Spectral and cepstral analysis. Temporal and spatial filtering. Geophysical modeling. Deconvolution, migration, and velocity analysis of reflection data. Downward and upward continuation of potential field data.

[**433 Interpretation of Seismic Reflection Data** Spring. 3 credits. Prerequisite: Geological Sciences 488 or equivalent. Not offered 1980–81.
2 lecs, 1 lab. L. D. Brown, S. Kaufman.
Techniques for inferring geologic structure and lithology from multichannel seismic reflection data. Data processing sequences, migration, velocity analysis, correlation criteria, resolution considerations, wave form analysis, and synthetic seismograms. Synergistic approaches to interpretation. Seismic stratigraphy.]

454 Modern Petrology Fall. 3 credits. Prerequisite: Geological Sciences 356. Offered alternate years.
2½ lecs, ½ lab. R. W. Kay.
Magmas and metamorphism in the context of plate tectonics. Major and trace element chemistry and phase petrology as monitors of the creation and modification of igneous rocks. Temperature and stress in the crust and mantle and their influence on reaction rates and textures of metamorphic rocks. Application of experimental studies to natural systems. Reading from the literature and petrographic examination of pertinent examples.

455 Isotope Geology Fall. 3 credits. Prerequisite: Geological Sciences 355–356 or equivalent.
3 lecs. R. W. Kay.
Nucleosynthetic processes and the isotopic abundance of the elements. Dating by Pb, Ar, Sr, and Nd isotope variations. Theories of crustal and mantle evolution. Pleistocene chronology using U-series and ^{14}C dating. Time constants for geochemical cycles. The use of O and H isotopes as tracers in the earth's hydrosphere, and hydrothermal circulation systems.

456 Chemical Geology Spring. 3 credits. Prerequisite: Geological Sciences 355–356 or equivalent.
3 lecs. W. A. Bassett, R. W. Kay.
Crystallography and crystal chemistry of minerals and the methods for their study. Thermodynamic evaluation of homogeneous and heterogeneous equilibrium and disequilibrium processes of geologic interest. Topics include crystal symmetry, mineral structures, x-ray diffraction, mineral equilibrium, and diffusion in minerals.

461 Mineral Deposits I Fall. 4 credits. Prerequisite: Geological Sciences 365 or permission of instructor.
3 lecs, 1 lab, field trip. A. K. Gibbs.
Introduction to mineral resources; sedimentary and magmatic deposits; topics in geochemistry; ore microscopy; and exploration methods.

462 Mineral Deposits II Spring. 4 credits. Prerequisite: Geological Sciences 461 or permission of instructor.
3 lecs, 1 lab, field trip. A. K. Gibbs.
Hydrothermal ore deposits; sulphide systems; related geochemical topics; mineral exploration.

471 Invertebrate Paleontology and Biostratigraphy Fall. 4 credits. Prerequisite: Geological Sciences 102 and 376 or permission of instructor. Recommended prerequisite: some knowledge of biology.
2 lecs, 1 lab. J. L. Cisne.
Fossil invertebrates. Anatomy, classification, and identification of stratigraphically important groups. Applications of paleontology to geochronology and reconstruction of past environments.

473 Stratigraphy Spring. 3 credits. Prerequisite: Geological Sciences 376 or permission of instructor.
2 lecs, 1 lab, field trip. S. B. Bachman.
Interaction of sedimentation and tectonics in development of stratigraphic sequences. Framework of deep ocean, active margin, passive margin, and cratonic sedimentation and stratigraphy. Seismic stratigraphy and the effects of sea-level changes on the stratigraphic record; sedimentary petrology and tectonism. Examples of modern and ancient margin and cratonic development.

[**483 Marine Tectonics** Fall. 3 credits. Prerequisites: Geological Sciences 325 and a course in physics or geophysics. Not offered 1980–81.
2 lecs, possible field trips. D. E. Karig.
Study of geophysical and geological characteristics of the earth's crust beneath the oceans. Review of strengths and limitations of marine exploratory techniques. Emphasis on recent geologic data concerning plate margins in the ocean, especially the island arc systems.]

[**485 Physics of the Earth I** Fall. 3 credits. Limited to upperclass engineers, majors in the physical sciences, and others by permission of instructor. Not offered 1980–81.
2 lecs, 1 lab. D. L. Turcotte.
Rotation and figure of the earth, gravitational field, seismology, geomagnetism, creep and anelasticity, radioactivity, earth's internal heat, continental drift, and mantle convection.]

488 Introduction to Geophysical Prospecting Fall. 3 credits. Prerequisites: Physics 112–213 and Mathematics 191–192, or equivalents, or permission of instructor.
2 lecs. S. Kaufman.
Physical principles, instrumentation, operational procedures, and interpretation techniques in geophysical exploration for oil, gas, and minerals. Seismic reflection, seismic refraction, gravity, and magnetic and electrical methods of exploration.

490 Senior Thesis Fall or spring. 2 credits.
Staff.
Thesis proposal to be discussed with adviser during the junior year. Participation requires acceptance of a thesis proposal by the faculty committee.

610–623 Seminars and Special Work Fall and spring. 2 or 3 credits each term. Prerequisite: permission of instructor.
Advanced work on original investigations in geological sciences. Topics change from term to term.

610 Tectonic and Stratigraphic Evolution of Sedimentary Basins W. B. Travers.

611 Petrology and Geochemistry R. W. Kay.

612 Coastal Geomorphology or Quaternary Geology A. L. Bloom.

613 Marine Geology D. E. Karig.

614 Sedimentary Petrology and Tectonics S. B. Bachman.

615 Topics in Mineral Resource Studies and Precambrian Geology A. K. Gibbs.

616 Plate Tectonics and Geology J. M. Bird.

617 Paleobiology J. L. Cisne.

618 Geophysics, Exploration Seismology L. D. Brown.

619 Earthquakes and Tectonics B. L. Isacks.

620 Exploration Seismology, Gravity, Magnetics S. Kaufman.

621 Geophysics, Seismology and Geotectonics J. Oliver.

622 Geomechanics, Gravity, Magnetism, Heat Flow D. L. Turcotte.

623 Mineralogy and Crystallography, X-ray Diffraction, Microscopy, High-Pressure-Temperature Experiments W. A. Bassett.

[**642 Glacial and Quaternary Geology** Spring. 3 credits.Prerequisite: Geological Sciences 345 or permission of instructor. Not offered 1980–81.
2 lecs, 1 lab; several Saturday field trips.
A. L. Bloom.
Glacial processes and deposits and the stratigraphy of the Quaternary.]

681 Geotectonics Fall. 4 credits. Prerequisite: permission of instructor.
2 lecs. J. M. Bird.
Theories of orogeny; ocean and continent evolution. Kinematics of lithosphere plates. Rock-time assemblages of modern oceans and continental margins, and analogs in ancient orogenic belts. Time-space reconstructions of specific regions. Problems of dynamic mechanisms — corollaries and evidence from crustal features.

685 Advanced Geophysics I Fall. 3 credits. Prerequisite: Geological Sciences 388 or 485.
3 lecs. D. L. Turcotte.
Mantle convection, heat flow, the driving mechanism for plate tectonics, the energy balance, definition of the lithosphere.

686 Advanced Geophysics II Spring. 3 credits. Prerequisite: Geological Sciences 388 or 485.
3 lecs. D. L. Tucotte.
Gravity, figure of the earth, earth tides, magnetism, mechanical behavior of the lithosphere, changes in sea level.

[**687 Seismology I** Fall. 3 credits. Prerequisite: T&AM 611 or equivalent. Offered alternate years. Not offered 1980–81.
3 lec-recs. B. L. Isacks.
Generation and propagation of elastic waves in the earth. Derivation of the structure of the earth and the mechanism of earthquakes from seismological observations.]

688 Seismology II Spring. 3 credits. Prerequisite: Geological Sciences 687.
B. L. Isacks.
A continuation of Geological Sciences 687.

Field Courses

[**601 Intersession Field Trip** January intersession. 1 credit. Prerequisites: Geological Sciences 101–102 or equivalent and permission of instructor. Travel and subsistence expenses to be announced. Not offered 1980–81.
A trip of one week to ten days in an area of interesting geology in the lower latitudes. Interested students should contact the instructor during the early part of the fall semester.]

604 Western Adirondack Field Course Spring. 1 credit.
One week at the end of the spring semester.
W. A. Bassett.
Field mapping methods, mineral and rock identification, examination of Precambrian metamorphic rocks and lower Paleozoic sediments, talc and zinc mines. Students should be prepared for overnight camping and will have to pay for their own meals.

704 Western Field Course Spring. 6 credits. Prerequisites: four courses in Geological Sciences at the 300 level, and permission of instructor. Students should be prepared for overnight camping and will have to pay for their own meals.
Weekly rec and 35-day trip to California, Nevada, and Utah. Staff.
A comparative study of California Coast Range, Sierra Nevada, Basin and Range of Nevada, and Uinta Mountains, Utah. Pretrip seminars and extensive reading at Cornell. Study of Mesozoic ophiolites, and subduction near San Luis Obispo, California; recent earth movements along the San Andreas fault near San Francisco; granitic pluton

emplacement and volcanism in the northern Sierra Nevada; multiplephase mountain building near Dixie Valley, Nevada; sedimentology and block faulting of the Uinta Mountains, Utah. Five-day raft trip on the Green River through the core of the Uinta mountains. Visit to an oil field in California and a mine in Nevada. Lectures and field trips with local experts.

Materials Science and Engineering

Undergraduate Courses

201 Elements of Materials Science Fall or spring. 3 credits.
Relations between atomic structure and macroscopic properties of such diverse materials as metals, ceramics, and polymers. Properties discussed include magnetism, superconductivity, insulation, semiconductivity, mechanical strength, and plasticity. Applications to microelectronics, desalinization by reverse osmosis, superconducting power transmission lines, synthetic bones and joints, etc. Extensive use of slides, audiotutorial systems, movies.

261 Introduction to Mechanical Properties of Materials Fall or spring. 3 credits.
2 lecs, 1 rec or lab.
See description under Division of Basic Studies.

262 Introduction to Electrical Properties of Materials Spring. 3 credits.
2 lecs, 1 rec or lab.
See description under Division of Basic Studies.

331 Structure and Properties of Materials Fall. 4 credits.
3 lecs, 1 lab.
The most widely used techniques to investigate materials such as metals, glasses, ceramics, and polymers; associated laboratory work teaches the use of the optical microscope and x-ray diffraction, and exposes the student to electron microscopy and the use and application of the scanning electron microscope. Discussion of how knowledge of microscopic structure obtained with these techniques can be used to predict and understand important engineering properties.

332 Electrical and Magnetic Properties of Materials Spring. 3 credits.
3 lecs.
An introduction to electrical and magnetic properties of materials with emphasis on structural aspects. Classification of solids, charge and heat transport in metals and alloys, semiconductors and insulators, principles of operation and fabrication of semiconductor devices, behavior of dielectric and magnetic materials, magnetic devices, phenomenological description of superconducting materials.

333 Research Involvement I Fall. 3 credits.
Prerequisite: approval of department.
Semi-independent research project in affiliation with faculty member and research group of the department.

334 Research Involvement II Spring. 3 credits.
Prerequisite: approval of department.
May be a continuation of MS&E 333 or a one-term affiliation with a research group.

335 Thermodynamics of Condensed Systems Fall. 3 credits.
3 lecs.
The various phases of materials and the changes that occur when temperatures and pressures change are considered by developing the laws of thermodynamics and applying them to different systems. The use of phase diagrams to predict the phase(s) of an alloy system at any given temperature and pressure in order to understand heat treatment such as the hardening of aluminum alloys and the quenching of steels. Phase transformations under conditions of quenching and their influence on hardness. Guidelines for heat treatment of steels.

336 Kinetics, Diffusion, and Phase Transformations Spring. 3 credits.
3 lecs.
Introduction to absolute rate theory, atomic motion, and diffusion. Applications to nucleation and growth of new phases in vapors, liquids, and solids; solidification, crystal growth, oxidation and corrosion, radiation damage, recrystallization, gas-metal reactions.

345 Materials and Manufacturing Processes (also M&AE 311) Fall or spring. 3 credits.
May be taken in addition to MS&E 261. Prerequisite: T&AM 202 or permission of instructor.
2 lecs, 1 lab.
See M&AE 311 for course description.

441 Microprocessing of Materials. Fall. 3 credits.
3 lecs, occasional lab.
The materials technology of electronic and magnetic devices; single crystals as well as thin films. Growth and purification (zone refining) of semiconducting crystals; doping procedures, including ion implantation; composition control; oxide growth; photoetching. Preparation of thin films by vapor deposition; sputtering; plating; evaluation of film geometry and composition. Material aspects of recent devices (superlattice growth, magnetic amorphous bubbles, etc.)

442 Macroprocessing of Materials Spring. 3 credits.
3 lecs, occasional lab.
Control of chemical composition through smelting, reaction, and refining processes; applications to iron and steel, aluminum, refractories, etc. Shape control; casting and solidification, welding; mechanical shaping through rolling, drawing, etc. Deformation and annealing, textures; relation to material properties. Thermomechanical treatments for control of material properties.

443–444 Senior Materials Laboratory 443, fall; 444, spring. 3 credits.
Experiments are available in structural studies, properties of materials, deformation and plasticity, mechanical and chemical processing, phase transformation, surface physics, etc.

445 Mechanical Properties of Materials Fall. 3 credits.
3 lecs.
The mechanical properties of materials and how they can be understood and analyzed in terms of microscopic irregularities (lattice defects) in perfect regular crystals. The general relation between stress and strain; the concept of equivalent stresses and strains. How the concept of local defects can explain many aspects of plastic flow, creep, fatigue, and rupture in classical and new engineering materials. Application of these concepts to the development of improved materials.

446 Current Topics in Materials Spring. 3 credits.
3 lecs.
Coordinated lectures on topics of current interest, such as biomaterials, fuel cells, composite materials, materials problems in power generation and distribution systems, stress corrosion cracking.

447 Introduction to Ceramics Fall. 3 credits.
Prerequisite: MS&E 261 or permission of instructor.
3 lecs.
Designed to develop an understanding of ceramic materials and processes for engineering applications. The crystallographic nature of some ceramics, and structural imperfections that can occur. Ionic motions in crystalline ceramics and their relation to properties and forming methods (such as sintering). Mechanical properties, such as cracking, in terms of microscopic mechanisms. The properties of some new ceramic materials, such as silicon nitride and barium titanate, in special applications.

448 Properties of Solid Polymers Spring. 3 credits.
3 lecs.
Inorganic, organic, and biological polymers. Physical properties of long-chain molecules. Molecular weight distribution and measurement. Gelation and the properties of networks. Rubber elasticity. Amorphous and crystalline polymers for engineering use; their structure and mechanical and thermal properties. Elements of composite material properties.

450 Physical Metallurgy Spring. 3 credits.
Control of microstructure and the relationships between microstructure and engineering properties of commercial alloys. Includes studies of iron and steel, aluminum, titanium, magnesium and copper-bond alloys, selected superalloys and cemented carbides. Emphasis is placed on phenomena and properties which make alloys useful as engineering materials. Topics include strengthening mechanisms, hardenability, environmental factors, and failure analysis.

452 Processing of Glass, Ceramic, and Glass-Ceramic Materials Fall. 3 credits.
Conventional and unconventional techniques for processing glass, ceramic, and glass-ceramic materials. Emphasis is given to the science of processing and to case studies. Applications include vapor processes for high-purity optical fibers, hot-pressing ceramic turbine blades, and nucleation of crystalline phases in glass to prepare photosensitive materials. This course is team taught with two scientists from the research and development laboratory of Corning Glass Works.

455 Analysis of Manufacturing Processes (also M&AE 512) Spring. 3 credits. Prerequisite: MS&E 337.
3 recs.
See M&AE 512 for course description.

Graduate-Level Professional Courses

553–554 Special Project 553, fall; 554, spring. 6 credits each term.
Research on a specific problem in the materials area.

Graduate Core Courses

601 Topics in Thermodynamics and Kinetics Fall. 3 credits.
The following topics are treated for condensed systems; free energy and phase equilibria; thermodynamics of solutions; interfaces; thermodynamics under applied fields; irreversible thermodynamics; reaction rate theory and diffusion.

602 Elasticity and Physical Properties of Crystals Fall. 3 credits.
Cartesian tensors, elastic stress and strain, constitutive relations between stress and strain, symmetry of crystals, generalized tensor representation of elasticity and other reversible and irreversible properties of crystals, mathematical theory of infinitesimal elasticity with applications including wave propagation and stress fields of dislocations, mathematical theory of yield stress and plasticity, origin of elastic behavior, including rubberlike behavior. At the level of *Physical Properties of Crystals* by Nye.

603 Structure of Solids Spring. 3 credits.
Prerequisites: MS&E 601 and 602, or equivalent.
Binding energies in perfect crystals. Structure and energetics of point; line and planar defects in crystalline materials, including metals, ionic solids, covalent solids, and polymers. Interactions between

defects. Bonding and random packing in amorphous materials. Observation of defects in crystalline materials. Structural analysis of amorphous materials.

604 Plastic Flow and Fracture of Materials Fall. 3 credits.
Experimental and theoretical aspects of the deformation and failure of structural materials. Although the emphasis is on metals and alloys, consideration is given also to glasses, ceramics, and polymeric materials. Some of the topics included are; theory and practice of mechanical testing, deformation behavior of polycrystal and single-crystal metals, phenomenological theories of deformation, micromechanical theories of plastic flow and creep, relationship of microstructure to mechanical properties, brittle and ductile fracture of materials.

605 Phase Transformations Spring. 3 credits. Prerequisites: MS&E 601, 602, and 603, or equivalent.
Nucleation theory. Growth theory. Formal theory of nucleation and growth transformation. Spinodal decomposition. Diffusionless transformations. Discussions of topics such as crystal growth from the vapor, solidification, eutectic transformations, solid state precipitation, eutectoid transformations, martensitic transformations. Transformations in polymers and glasses. At the level of *Phase Transformations,* American Society of Metals. 1970.

Related Course in Another Department

Introductory Solid-State Physics (Physics 454)

Further Graduate Courses

610 Principles of Diffraction (also A&EP 711)
Fall. 3 credits. Offered alternate years.
Introduction to diffraction phenomena as applied to solid-state problems. Scattering and adsorption of neutrons, electrons, and x-ray beams. Diffraction from two- and three-dimensional periodic lattices. Fourier representation of scattering centers, and the effect of thermal vibrations. Phonon information from diffuse x-ray and neutron scattering and Bragg reflections. Diffraction from almost-periodic structures, surface layers, gases, and amorphous materials. Survey of dynamical diffraction from perfect and imperfect lattices.

614 Electron Microscopy 3 credits.
Electron optics, Abbé theory of image formation with applications to the direct imaging of small defects and atomic planes. Kinematical theory of diffraction with applications to the study of the structure of grain boundaries and the imaging of crystal defects. Dynamical theory of diffraction as applied to the calculation of the images of crystal defects. Instruction in the use of the microscope.

669 Ceramic Materials 3 credits. Prerequisites: MS&E 601 and some familiarity with crystal structures.
Crystal structure and bonding of typical ceramic materials; structure of silicate and nonsilicate glasses; imperfections in oxides; point defects and point defect chemistry, line defects, extended defects; diffusion in stoichiometric and nonstoichiometric ceramics; phase transformations; equilibrium and nonequilibrium phases; grain growth and sintering; plastic deformation and creep; topics from research papers.

701 Electrical and Magnetic Properties of Materials 3 credits. Prerequisite: Physics 454 or equivalent.
Electronic transport properties of metals and semiconductors, semiconductor devices, optical and dielectric properties of insulators and semiconductors, laser materials, dielectric breakdown, structural aspects of superconducting materials, ferromagnetism and magnetic materials. At the level of *Physics of Semiconductor Devices* by Sze, *Ferromagnetism* by Bozworth, and current review articles.

702 Amorphous and Semicrystalline Materials 3 credits. Prerequisite: Physics 454 or equivalent.
Topics related to the science of the amorphous state selected from within the following general areas: structure of liquids and polymers; rheology of elastomers and glasses; electrical, thermal, and optical properties of amorphous materials. Presented at the level of *Modern Aspects of the Vitreous State* by Mackenzie, *"Glass Transitions"* by Shen and Eisenberg in *Progress in Solid State Chemistry,* and *The Physics of Rubber Elasticity* by Treloar.

703 Physics of Solid Surfaces (also A&EP 762) 3 credits. Prerequisites: MS&E 601 and some knowledge of solid-state physics.
See A&EP 762 for course description.

704 Advanced Topics in Crystal Defects 3 credits. Prerequisites: MS&E 601, 602, and 603, or equivalent.
The structure and properties of point, line, and planar crystal defects treated from a fundamental point of view. Thermodynamics and kinetics of point defects. Atomistic and continuum theories of dislocations. Thermodynamic treatment of grain boundaries. Structure of grain boundaries. Emphasis given throughout to interactions between the various types of defects and to their roles in important phenomena such as diffusion, precipitation, plasticity, radiation damage.

705 The Effects of Radiation on Materials 3 credits.
Cross section for atom displacement; orientation dependence of the threshold energy; interatomic potentials; the atomic collision cascade; focusing of atomic collisions; mass transport along collision spectra within a cascade; range concepts and measurements in polycrystalline and single crystal metals and semiconductors; channeled particles and the effect of crystal imperfections on the range; Rutherford back-scattering and channeling and their application to the lattice location of impurity atoms; sputtering of single and polycrystalline metals; recovery mechanisms for radiation damage; void formation in metals irradiated to high fluences and the problem of swelling in liquid metal fast breeder reactors; the first-wall problem in controlled thermonuclear reactors. At the level of *Defects and Radiation Damage in Metals* by M. W. Thompson, *The Observation of Atomic Collisions in Crystalline Solids* by R. S. Nelson, *Ion Bombardment of Solids* by G. Carter and J. S. Colligon, and selected papers and review articles.

706 Amorphous Semiconductors 2 credits. Prerequisite: knowledge of the theory of crystalline semiconductors on the level of Kittel.
The preparation, characterization, and the electronic transport of amorphous semiconductors from an experimental point of view. Particular emphasis is given to amorphous, hydrogenated Si. Some potential device applications, such as in amorphous Si solar cells and the metal-base transistor, are described.

707 Solar Energy Materials 3 credits.
3 lecs.
Photovoltaic energy conversion: (1) theory (on the level of Hovel); (2) the role of crystal defects and grain boundaries on the conversion efficiency, and schemes to passivate these defects; (3) current investigations in the JPL program to produce large quantities of solar-grade semiconducting Si.

775 Advanced Topics in Mechanical Properties 3 credits. Prerequisite: MS&E 604 or permission of instructor.
3 lecs.
Topics from current research in mechanical properties of structural materials, selected from the following: modern theories of deformation, high-strength alloys, effects of nuclear radiation, amorphous solids, cyclic deformation and fatigue, fracture of brittle and ductile solids, anelasticity and internal friction. Lectures are based largely on current literature.

779 Special Studies in Materials Sciences Fall or spring. Credit variable.
Supervised studies of special topics in materials science.

798 Materials Science and Engineering Colloquium Fall and spring. 1 credit each term. Credit limited to graduate students.
Lectures by visiting scientists, Cornell staff members, and graduate students on subjects of interest in materials science, especially in connection with new research.

799 Materials Science Research Seminars Fall and spring. 2 credits each term. For graduate students involved in research projects.
Short presentations on research in progress by students and staff.

800 Research in Materials Science Fall and spring. Credit to be arranged. Prerequisite: candidacy for Ph.D. in Materials Science.
Independent research in materials science under the guidance of a member of the staff.

801 Research in Materials Science Fall and spring. Credit to be arranged. Prerequisite: candidacy for M.S. in Materials Science.
Independent research in materials science under the guidance of a member of the staff.

Mechanical and Aerospace Engineering

101 Naval Ship Systems Spring. 3 credits. Limited to freshmen and sophomores.
R. L. Wehe.
An introduction to primary ship systems and their interrelation. Basic principles of ship construction, stability, propulsion, control, internal communications, and other marine systems.

221 Thermodynamics Fall or spring. 3 credits. Prerequisites: Mathematics 191 and 192, Physics 112.
3 recs.
See description under Division of Basic Studies.

302 Technology, Society, and the Human Condition Spring. 3 credits. Limited to 40 upperclass engineers and other students who have received permission of instructor. S-U grades optional.
B. J. Conta.
An introduction to the history of technology from the origin of man to the present. Emphasis is on the social and human consequences of technology rather than on internal or gadget history. Of primary interest is the nineteenth and twentieth centuries and the pervasive effects of industrialization — a process that began with manufacturing and was rapidly extended to agriculture, culminating in what Ivan Illich has called the industrialization of man. Among the current topics included are the transition from an economy of abundance and affluence to one of impending shortages and limits to growth, alternative life styles, alternative energy sources and systems, and the growing interest in intermediate or appropriate technology.

305 Introduction to Aeronautics Fall. 3 credits. Limited to upperclass engineers and students who have received permission of instructor.
D. A. Caughey.
Introduction to atmospheric flight vehicles. Principles of incompressible and compressible aerodynamics, boundary layers, and wing theory. Propulsion system characteristics. Static aircraft performance; range and endurance. Elements of stability and control.

311 Materials and Manufacturing Processes (also MS&E 345) Fall or spring. 3 credits. May be taken in addition to MS&E 261. Prerequisite: T&AM 202.
2 lecs, 1 lab.
Material structures. Physical and metallurgical properties of materials and their control by mechanical and metallurgical means. Manufacturing processes. Emphasis on correlations among design, material properties, and processing methods.

323 Fluid Mechanics Fall or spring. 4 credits. Prerequisites: M&AE 221, T&AM 202 and 203, or permission of instructor.
4 recs.
Statics, kinematics, potential flow, dynamics, momentum and energy relations. Thermodynamics of compressible flow; dimensional analysis; real fluid phenomena, laminar and turbulent motion, boundary layer; lift and drag; supersonic flow.

324 Heat Transfer and Transport Processes Fall or spring. 3 credits. Prerequisite: M&AE 323.
1 lec, 2 rec.
Conduction of heat in steady and unsteady situations. Fin surfaces and systems with heat sources. Emission and absorption of radiation, and radiative transfer between surfaces. Forced and natural convection of heat owing to flow around bodies and through ducts. Combined modes of transfer and heat exchangers.

325 Mechanical Design and Analysis Fall or spring. 4 credits. Prerequisites: T&AM 202 and 203.
3 recs, 1 lab.
Application of the principles of mechanics and materials to problems of analysis and design of mechanical systems.

326 Systems Dynamics Fall or spring. 4 credits. Prerequisite: M&AE 325.
Dynamic behavior of mechanical systems, modeling, analysis techniques and applications, digital- and analog-computer simulation, balancing of rotating and reciprocating machinery, vibrations of single and multi-degree-of-freedom systems, linear control systems. PDF control, stability analysis.

389 Computer-Aided Design Spring. 3 credits. Limited to juniors and seniors.
2 lec-recs, 1 computing lab; term project.
A broad introduction to computational methods in mechanical design.

[439 Acoustics and Noise Spring. 3 credits. Prerequisite: some knowledge of fluid mechanics or permission of instructor. Not offered 1980–81.
A. R. George.
Sound propagation, transmission, and absorption. Sound radiation by surfaces and flow. Loudspeakers. Hearing, music, noise, and noise control criteria. Room acoustics and noise control techniques.]

449 Combustion Engines Fall. 3 credits. Prerequisite: M&AE 221.
3 recs.
Introduction to combustion engines, with emphasis on application of thermodynamics and fluid dynamics and on control of undesirable exhaust emissions. Emphasis on performance, efficiency, and emissions of current and future spark-ignited and diesel reciprocating engines. Discussion of alternative engines and fuels.

453 Mechanical Engineering Laboratory Fall. 4 credits. Prerequisites: M&AE 325, 323, and concurrent registration in M&AE 326 and 324.
1 lec, 2 labs.
Laboratory exercises in instrumentation, techniques, and methods in mechanical engineering. Measurements of pressure, temperature, heat flow, drag, fluid flow rate, solar energy, thermoelectricity, displacement, force, stress, strain, vibrations, noise, etc.

459 Plasma Energy Systems Spring; offered on demand. 3 credits. Prerequisite: Physics 214.
Fundamental aspects of plasma physics. An elementary treatment of principles on which the concepts of controlled thermonuclear (fusion) reactors are based. Comparisons between fission and fusion systems and treatment of other plasma devices (e.g., MHD converters) as time permits.

464 Design for Manufacture Fall. 3 credits. Prerequisites: M&AE 311 and 325, or permission of instructor.
Design for casting, forging, stamping, welding, machining, heat treatment, and assembly; beneficial prestressing; improving the distribution of loads and deflections. Selection of materials; dimensioning and fits; joints, fasteners, and shaft mountings. Specifications for manufacturing and maintenance to minimize fatigue failures and improve reliability. Short design problems.

[483 Mechanical Reliability Spring. 3 credits. Prerequisite: OR&IE 260 or 270 or equivalent. Not offered 1980–81.
S. L. Phoenix.
Classic system reliability, hazard function concepts, reliability bounds; static and time-dependent material strength models, static and dynamic fatigue, weakest flaw models; structural system reliability, static and time-dependent parallel member models. Monte Carlo simulation of structural systems with load sharing.]

486 Automotive Engineering Spring. 3 credits. Prerequisite: M&AE 325.
Selected topics in the analysis and design of vehicle components and vehicle systems. Emphasis is on automobiles, trucks, and related vehicles. Powerplant, driveline, brakes, suspension, and structure. Other vehicle types may be considered.

490 Special Investigations in Mechanical and Aerospace Engineering Fall or spring. Credit to be arranged. Prerequisite: permission of instructor. Limited to undergraduate students.
Intended for an individual student or a small group of students who want to puruse a particular analytical or experimental investigation outside of regular courses, or for informal instruction supplementing that given in regular courses.

[506 Aerospace Propulsion Systems Spring. 3 credits. Prerequisite: M&AE 323 or permission of instructor. Offered alternate years. Not offered 1980–81.
3 recs. F. C. Gouldin.
Application of thermodynamics and fluid mechanics to design and performance of thermal-jet and rocket engines. Mission analysis in space. Auxiliary power supply; study of advanced methods of space propulsion.]

507 Dynamics of Flight Vehicles Spring. 3 credits. Prerequisites: M&AE 305 and T&AM 203 or permission of instructor. Offered alternate years.
D. A. Caughey.
Introduction to stability and control of atmospheric flight vehicles. Review of aerodynamic forces and methods for analysis of linear systems. Static stability and control. Small disturbance equations of unsteady motion. Dynamic stability and transient control response. At the level of *Stability and Control of Airplanes and Helicopters* by Seckel.

512 Analysis of Manufacturing Processes (also MS&E 455) Spring. 3 credits. Prerequisite: M&AE 311.
3 lecs.
Analytical treatment of metal cutting and metal forming processes; conventional and nontraditional manufacturing methods; production systems and machine tool dynamics.

513 Materials Engineering Spring. 3 credits. Prerequisite: M&AE 311 or MS&E 261 or permission of instructor.
Designed to aid in the design, selection, and use of engineering materials. Theory and practice of extractive, physical, and mechanical metallurgy. Corrosion principles and control; metallurgical failure analysis and prevention; mechanical properties of polymers, ceramics, and composite materials.

514 Numerical Control in Manufacturing Fall. 3 credits.
3 lecs. K. K. Wang.
Principles and the state of the art of numerical control (NC) technology; programming methods for NC and computerized NC (CNC) machine tools with laboratories; economic aspects, and roles in computer-aided design/computer-aided manufacturing (CAD/CAM) systems.

536 Turbomachinery and Applications Spring. 3 credits. Prerequisite: M&AE 323 or permission of instructor.
3 recs.
Aerothermodynamic design of turbomachines in general, energy transfer between fluid and rotor in specific types, axial and radial units, compressible flow. 3-D effects, surging.

543 Combustion Processes Spring. 3 credits. Prerequisites: M&AE 323, 324.
3 recs.
An introduction to combustion and flame processes with emphasis on fundamental fluid dynamics, heat and mass transport, and reaction-kinetic processes that govern combustion rates. Both premixed and diffusion flames are considered.

554 Solar Engineering Fall. 3 credits. Prerequisite: M&AE 221. Offered alternate years.
Fundamentals of solar radiation. Solar collection and thermal conversion. Solar energy applications to environmental living systems. Generation of solar electric power and photovoltaic conversion. Alternate uses of solar energy. Systems analysis and economics.

[555 Direct Energy Conversion and Storage Spring. 3 credits. Prerequisite: M&AE 221 or equivalent. Offered alternate years. Not offered 1980–81.
3 lecs.
Primarily a survey of methods for the direct conversion of heat into electrical energy, with emphasis on efficiency, maximum power, practical applications, and limitations. Thermoelectric generators and refrigerators. Thermionic generators. Solar cells. Batteries. Fuel cells.]

556 Power Systems Fall. 3 credits. Prerequisite: M&AE 323 or equivalent.
F. K. Moore.
A broad survey of methods of large-scale power generation, emphasizing energy sources, thermodynamic cycle considerations, and component description. Power industry, economic, and environmental factors. Trends and projections.

557 Future Energy Systems Seminar Spring. 3 credits. Prerequisite: an energy-related course.
Options for future energy-conversion systems or power generation, transportation, and other end-use applications. Technical feasibilities, benefits, and environmental impacts are considered. Classes or seminars based on study projects that reflect student preparation and interests, conducted with faculty advice.

563 Mechanical Components Spring. 3 credits. Prerequisite: M&AE 325.
Advanced analysis of machine components and structures. Application to the design of new configurations and devices. Selected topics from the

following: lubrication theory and bearing design, fluid drives, shells, thick cylinders, rotating disks, fits, elastic-plastic design, thermal stresses, creep, impact, indeterminate and curved beams, plates, contact stresses.

565 Biomechanical Systems — Analysis and Design Spring. 3 credits. Prerequisites: T&AM 202 and 203.
3 recs; term project. D. L. Bartel.
Selected topics from the study of the human body as a mechanical system. Emphasis on the modeling, analysis, and design of biomechanical systems frequently encountered in orthopedic surgery and physical rehabilitation.

569 Mechanical and Aerospace Structures I Fall. 3 credits. Prerequisite: M&AE 325 or permission of instructor.
A study of advanced topics in the analysis of stress and deformation of deformable bodies with applications to the analysis and design of mechanical and aerospace systems. Topics selected from advanced strength of materials, energy methods in stress analysis, strength theories, and experimental stress analysis.

570 Mechanical and Aerospace Structures II Spring. 3 credits. Term project. Prerequisite: M&AE 569 or permission of instructor.
J. F. Booker.
Introduction to modern computational methods for static and dynamic analysis of mechanical and aerospace structures. Emphasis on underlying mechanics and mathematics. Discussion of inherent capabilities and limitations of general-purpose structural mechanics programs (e.g., NASTRAN). Selected applications, structural and otherwise, of the finite element method.

577 Mechanical Vibrations Spring. 3 credits. Open to qualified undergraduates. Prerequisite: M&AE 326 or equivalent.
2 recs, 1 lab.
Further development of vibration phenomena in single-degree and multidegree of freedom linear and nonlinear systems, with emphasis on engineering problems involving analysis and design.

578 Feedback Control Systems Fall. 3 credits. Open to qualified undergraduates. Prerequisite: M&AE 326 or equivalent.
2 recs, 1 lab. R. M. Phelan.
Further development of the theory and implementation of feedback control systems, with particular emphasis on the application of pseudo-derivative-feedback (PDF) control concepts to linear and nonlinear systems.

[587 Dynamics of Vehicles Fall. 3 credits. Prerequisite: T&AM 203. Offered alternate years. Not offered 1980–81.
Introduction to the dynamics of ground vehicles including cars, trucks, trailers, motorcycles, and railroad vehicles. Emphasis is on the handling behavior and stability of the automobile, tire theory, and suspension analysis. Performance and comfort criteria are developed. Further topics are included to reflect interests of the class.]

590 Design Project in Mechanical Engineering Fall and spring. 3 credits each term. Intended for students in M.Eng.(Mechanical) degree program. Design of an engineering system or a device of advanced nature. Projects by individuals or small groups, sometimes in collaboration with an external organization.

592 Seminar and Design Project in Aerospace Engineering Fall and spring. 2 credits each term. Intended for students in M.Eng.(Aerospace) program. Study and discussion of topics of current research interest in aerospace engineering. Individual design projects.

602 Incompressible Aerodynamics Spring. 3 credits. Intended for graduate students interested in fluid dynamics or aerodynamics research. Open to qualified undergraduates with permission of instructor.
Basic equations, vorticity and flow development. Incompressible potential flow theory; singularity distributions, airfoil, wing, and slender body theory, complex-variable methods, unsteady phenomena.

603 Compressible Aerodynamics Fall. 3 credits. Prerequisite: M&AE 632 or equivalent. Open to qualified undergraduates with permission of instructor.
Basic conservation laws and fundamental theorems of compressible fluid flow. Shock waves, method of characteristics, wave interactions. Perturbation theories and similarity rules. Expansion procedures and singular perturbation problems. Linearized supersonic flow, wing theory, wave drag. Nonlinear theories of transonic and supersonic flow.

608 Physics of Fluids I Fall. 3 credits.
Elementary kinetic theory of gases and a microscopic derivation of the Navier-Stokes equations. Statistical mechanics and applications to gas reactions. Elementary chemical kinetics as related to pollution studies.

609 Physics of Fluids II Spring, on demand. 3 credits.
Molecular structure bonding theory, heats of reaction. Atomic and molecular spectroscopy, applications to pollution. Nonequilibrium statistical mechanics; Boltzmann equation, H-theorem, review of Hilbert-Enskog-Chapman theory, fluctuations. Onsager's relations. Radiative transfer; lasers. At the level of *The Dynamics of Real Gases* by Clarke and McChesney.

610 Gasdynamics Spring. 3 credits. Offered on demand.
E. L. Resler, Jr.
A survey of the nonlinear theory of characteristics as applied to two-dimensional steady supersonic flows and one-dimensional unsteady flows. The role of chemical reactions in these flows is treated, as well as experimental techniques to measure chemical reaction rates. Among the topics treated are heat capacity lag and its effects on acoustics, gasdynamic lasers, and shock-tube techniques. Magnetically driven shock waves are also considered, if time permits.

616 Finite Element Methods in Thermo-mechanical Processes Fall. 3 credits. Prerequisites: introductory course work in finite element methods and elasticity, or in analysis of manufacturing processes.
P. R. Dawson.
Application of finite element methods in the analyses of mechanical deformation processes that are nonlinear and influenced by coupling to thermal or electrical behavior. Elastic, elastoplastic, viscoplastic, and thermally coupled analyses applied to problems in large deformation, bulk forming, polymer flows, and welding.

[630 Atmospheric Turbulence and Micrometeorology Spring. 3 credits. Offered alternate years. Not offered 1980–81. Open to qualified undergraduates with permission of instructor.
Z. Warhaft.
Basic problems associated with our understanding of the structure of the velocity field and the transport of scalars such as temperature and moisture in the lower atmosphere, from both theoretical and experimental viewpoints. Topics include the second-order turbulence equations and their closure, Monin-Obukhov theory, diffusion of scalars, spectral characteristics of atmospheric variables, experimental techniques including remote sensing, and the analysis of random time series.]

632 Theoretical Fluid Mechanics and Aerodynamics I Fall. 3 credits.
Introduction to the mechanics of fluids. Derivation of the Navier-Stokes equations. Boundary conditions. Exact solutions. Vorticity theorems. Methods of solution of irrotational flows. Thin airfoil and wing theory. Boundary layer theory. Exact methods of solution of the boundary layer equations.

633 Theoretical Fluid Mechanics II Spring. 3 credits.
Approximate methods in boundary layer theory. Stability of fluid flow. Introduction to turbulent flows. Dynamics and thermodynamics of compressible flows. Sound waves. Subsonic and supersonic flow. One-dimensional steady flows. One-dimensional unsteady flows, method of characteristics, shock waves.

[648 Seminar on Combustion Spring. 3 credits. Prerequisite: permission of instructor. Offered alternate years. Not offered 1980–81.
3 recs.
Discussion of contemporary problems in combustion research with emphasis on applications of modern experimental and analytical techniques. Typical problems include formation and removal of pollutants in combustion systems, combustion of alternative fuels, coal combustion, and modification of combustion systems for energy efficiency improvement.]

650 Transport Processes I Fall. 3 credits. Prerequisite: M&AE 324 or permission of instructor.
K. E. Torrance.
Advanced treatment of heat conduction and thermal radiation. Differential and integral conduction equations. Exact and approximate solutions; superposition; phase change boundaries. Radiative transport equation and Kirchhoff's laws. Emission and scattering by real surfaces and by gases. Heat exchange in enclosures.

651 Transport Processes II Spring. 3 credits. Prerequisites: M&AE 323, 324, or permission of instructor.
Advanced convection heat transfer. Integral and differential formulations. Basic equations reasoned in detail. Exact and approximate solutions. Natural convection. Forced convection. Laminar, transitional, and turbulent flows. Effects of variable properties, viscous dissipation, and compressibility. Mass transfer. Boiling and condensation.

653 Experimental Methods in Fluid Mechanics and Combustion Fall. 3 credits.
2 lecs, 1 lab. F. C. Gouldin.
Study of experimental techniques and data analysis procedures for investigation of fluid and combustive systems, with emphasis on experimental capabilities, underlying principles, and statistical treatment of data. Topics include laser velocimetry, hot-wire anemometry, and spectroscopy.

[672 Experimental Methods in Machine Design Fall. 3 credits. Prerequisite: M&AE 325 or equivalent. Not offered 1980–81.
1 rec, 2 labs.
Investigation and evaluation of methods used to obtain design and performance data. Photoelasticity, strain measurement, photography, vibration and sound measurements, transducers.]

[676 Advanced Mechanical Vibrations Fall. 3 credits. Prerequisite: M&AE 577 or equivalent. Offered alternate years. Not offered 1980–81.
D. L. Taylor.
Vibratory response of multi-degree-of-freedom systems, matrix formulation, concepts of impedance, mobility, frequency response, and complex mode shapes. State-of-the-art techniques such as FFT, sine sweep, and single-point random excitation. Nonlinear vibrations, limit cycle analysis, parametric resonance,

self-excited oscillations, and nonconservative systems. Random vibrations and stochastic excitation. Introduction to vibrations of elastic bodies.]

679 Digital Simulation of Dynamic Systems Fall. 3 credits. Open to qualified undergraduates by permission of instructor. Prerequisite: previous exposure to systems dynamics and digital programming. Offered alternate years.
J. F. Booker.
Modeling and representation of physical systems by systems of ordinary differential equations in vector form. Applications from diverse fields. Simulation diagrams. Analog and digital simulation by direct integration. Problem-oriented digital-simulation languages (e.g., CSMP). Digital analysis of stability and response of large linear systems.

680 Design of Complex Systems Offered on demand. 3 credits. Prerequisite: permission of instructor.
Two 2-hour meetings. R. L. Wehe.
Seminars rely heavily on student participation in discussing frontier problems such as systems for space and underwater exploitation, salt water conversion, and transportation. Reports including recommendations and the reasoning that led to them are required.

682 Hydrodynamic Lubrication Offered on demand. 3 credits.
J. F. Booker.
Designed to acquaint those having a general knowledge of solid and fluid mechanics with the special problems and literature currently of interest in various fields of hydrodynamic lubrication. General topics include equations of viscous flow in thin films, self-acting and externally pressurized bearings with liquid and gas lubricant firms, bearing-system dynamics, and computational methods. Also selected special topics, such as elastohydrodynamic lubrication.

[684 Advanced Mechanical Reliability Fall. 3 credits. Prerequisite: M&AE 483 or permission of instructor. Offered alternate years. Not offered 1980–81.
S. L. Phoenix.
Advanced course in random loading and statistical failure processes in mechanical systems. Continuous and discrete random loadings, random vibrations of mechanical structures, random fatigue processes in materials, order statistics and statistical estimation, reliability, simulation, and computation in mechanical structures, coherent systems and monotone load-sharing, stochastic failure of bundles and composites.]

685 Optimum Design of Mechanical Systems Spring. 3 credits. Prerequisite: graduate standing or permission of instructor.
3 recs. D. L. Bartel.
The formulation of design problems frequently encountered in mechanical systems as optimization problems. Theory and application of methods of mathematical programming for the solution of optimum design problems.

690 Special Investigations in Mechanical and Aerospace Engineering Fall or spring. Credit to be arranged. Limited to graduate students.

695 Special Topics in Mechanical and Aerospace Engineering Fall or spring. Credit arranged. Prerequisite: permission of instructor.
Lecture or seminar format.
Topics of current importance in mechanical and aerospace engineering and research. More than one topic may be taken if offered.

704 Viscous Flows Spring. Offered on demand. 3 credits. Prerequisite: M&AE 632 or equivalent.
S. F. Shen.
A systematic study of laminar flow phenomena and methods of analysis. Exact solutions of the Navier-Stokes equations. The small Reynolds number approximation. Matched asymptotic expansion. The boundary layer approximation; general properties. Transformations for compressibility and axisymmetric effects. Approximate methods of calculation. Unsteady problems. Stability of laminar flows.

707 Aerodynamic Noise Theory Offered on demand. 3 credits. Prerequisites: M&AE 632 or permission of instructor.
Advanced topics in acoustics relevant to aerodynamic and transportation noise sources and control. Random processes. Geometrical acoustics in inhomogeneous moving media, Kirchhoff and Poisson formulas, diffraction, scattering. Lighthill-Curle formulations for sound generation. Absorption and transmission in fluids and at boundaries. Applications to aerodynamic noise sources.

734 Turbulence and Turbulent Flow Fall. 3 credits.
J. L. Lumley.
Topics include the dynamics of buoyancy and shear-driven turbulence, boundary-free and bounded shear flows, second-order modeling, the statistical description of turbulence, turbulent transport, and spectral dynamics.

735 Dynamics of Rotating Fluids Offered on demand. 3 credits. Prerequisites: M&AE 632–633.
S. Leibovich.
Review of classical fluid mechanics. Rotating coordinate systems. Linearized theory for rapidly rotating fluids. Inviscid regions, viscous layers. Spinup. Motions past objects. Waves in rotating fluids. Motions in concentrated vortices. "Vortex breakdown" in swirling flows. Boundary layer interactions.

737 Numerical Methods in Fluid Flow and Heat Transfer Spring. 3 credits. Prerequisites: M&AE 323, 324 and some FORTRAN programming.
K. E. Torrance.
Discretization procedures for the Navier-Stokes and scalar transport equations. Finite differences and finite elements. Analysis of accuracy, stability, and convergence. Survey and comparison of current methods with applications. Assigned problems are solved with a digital computer.

738 Nonlinear Wave Propagation Offered on demand. 3 credits.
S. Leibovich.
Mathematical treatment of nonlinear effects associated with waves in continua. Examples are taken primarily from geophysical fluid dynamics and gas dynamics. Methods of averaging, variational methods, wave interactions, and exact solutions of nonlinear evolution equations.

791 Mechanical and Aerospace Engineering Research Conference Fall and spring. 1 credit each term.
For graduate students involved in research projects. Short presentations on research in progress by students and staff.

799 Mechanical and Aerospace Engineering Colloquium Fall and spring. 1 credit each term. Credit limited to graduate students. All students and staff invited to attend.
Lectures by Cornell staff members, graduate students, and visiting scientists on topics of interest in mechanical and aerospace science, especially in connection with new research.

890 Research in Mechanical and Aerospace Engineering Credit to be arranged. Prerequisite: candidacy for M.S. degree in mechanical or aerospace engineering, or approval of the director. Independent research in an area of mechanical and aerospace engineering under the guidance of a member of the staff.

990 Research in Mechanical and Aerospace Engineering Credit to be arranged. Prerequisite: candidacy for Ph.D. degree in mechanical or aerospace engineering or approval of the director. Independent research in an area of mechanical and aerospace engineering under the guidance of a member of the staff.

Nuclear Science and Engineering

A number of courses in nuclear sciences and engineering are offered through the School of Applied and Engineering Physics; see A&EP 303, 304, 609, 612, 613, 633, 634, 636, 638, 651, and 652.

605 Interaction of Radiation and Matter Spring. 4 credits. Prerequisite: a course in modern physics including quantum mechanics.
3 lecs. V. O. Kostroun.
Quantization of the electromagnetic field; relativistic wave equation of the electron; electrons interacting with radiation field — emission, absorption, dispersion, photoelectric effect. Compton scattering, scattering of two electrons, bremsstrahlung, pair production, and annihilation; passage of heavy charged and neutral particles through matter. Examples and applications from low-energy nuclear, plasma, and solid-state physics.

Operations Research and Industrial Engineering

120 Nature of Systems and Operations Analysis Fall or spring. 1 or 2 credits.
1 lec, 1 rec.
Introductory topics in operations research. Can be taken as a six-week, 1-credit minicourse in either half of either term, or as a 2-credit course in either full term. Generally taken as part of DBS 106, in which case the student registers only for DBS 106.

213 Systems Analysis and Design Fall. 3 credits. Prerequisite: first-year calculus.
2 lecs, 1 rec.
See description under Division of Basic Studies.

260 Introductory Engineering Probability Fall or spring. 3 credits. Prerequisite: first-year calculus.
3 lecs.
See description under Division of Basic Studies.

270 Basic Engineering Statistics Fall or spring. 3 credits. Prerequisite: first-year calculus.
2 lecs, 1 rec.
See description under Division of Basic Studies.

320 Optimization I Fall. 4 credits. Prerequisite: Mathematics 293 or 221.
3 lecs, 1 rec.
Formulation of linear programming problems and solution by the simplex method. Related topics such as sensitivity analysis, duality, and network programming. Applications include such models as resource allocation and production planning.

321 Optimization II Spring. 3 credits. Prerequisite: OR&IE 320 or equivalent.
2 lecs, 1 lec-rec.
A variety of optimization methods, stressing extensions of linear programming and its applications but also including topics drawn from integer, dynamic, and nonlinear programming. Formulation and modeling are stressed, as well as numerous applications. The computer is used in solving typical problems.

350 Cost Accounting, Analysis, and Control Fall or spring. 4 credits.
3 lecs, 1 computing-disc.

Principles of accounting, financial reports; job order and process cost systems — historical and standard costs; cost characteristics and concepts for control, analysis, and decision making.

361 Introductory Engineering Stochastic Processes I Spring. 4 credits. Prerequisite: OR&IE 260 or equivalent.
3 lecs, 1 rec.
Basic concepts and techniques of random processes are used to construct models for a variety of problems of practical interest. Topics include the Poisson process, Markov chains, renewal theory, models for queueing and reliability.

370 Introduction to Statistical Theory with Engineering Applications Fall or spring. 4 credits. Prerequisite: OR&IE 260 or equivalent.
3 lecs, 1 rec.
Provides a working knowledge of basic statistics as it is most often applied in engineering and a basis in statistical theory for continued study. Topics include a review of distributions of special interest in statistics; testing simple and composite hypotheses; point and interval estimation; correlation; linear regression; curve fitting.

383 Introduction to Simulation and Database Systems Spring. 4 credits. Prerequisite: Computer Science 211.
2 lecs, 1 rec; substantial programming exercises.
First third of course concerns discrete-event simulation: problems of modeling, programming, and experimental investigation. Balance of course is an introduction to modern database systems: basic models of file organization and access strategies and problems of file maintenance and information retrieval.

410 Industrial Systems Analysis Fall. 4 credits. Prerequisites: OR&IE 350 and 370.
3 lecs, 1 computing session.
Engineering economic analysis, including engineering economy, replacement, taxation effects, decision making based on economic considerations. Operations analysis including process flow, process evaluation, procedural analysis, resource layout, methods analysis ard design, work measurement, job evaluation, quality control elements. Project planning and control.

417 Layout and Material Handling Systems Spring. Prerequisites: OR&IE 361 and 383.
2 lecs, 1 rec.
Design of the layout of processes and storage areas and the material handling system for movement of items. Typical equipment used. The functions of identification, control, storage, movement, batching, merging, and dispersion. Introduction to new technologies.

421 Production Planning and Control Spring. 4 credits. Prerequisites: OR&IE 320 and 361 or permission of instructor.
3 lecs.
Planning and control of large-scale production operations. Inventory control. Leveling, smoothing, and scheduling of production. Job shop scheduling and dispatching. Demand forecasting. Economic and practical interpretation of planning and control procedures.

[431 Discrete Models Spring. 3 credits. Prerequisite: OR&IE 320 or permission of instructor. Not offered 1980–81.
3 lec-recs.
Basic concepts of graphs, networks, and discrete optimization. The use of finite mathematical techniques to model contemporary problems selected from operations research, including voting procedures and decision making, efficient and equitable allocations, energy and environment, traffic and urban systems.]

432 Introductory Nonlinear Programming Spring. 3 credits. Prerequisites: OR&IE 320. Computer Science 100.
2 lecs, 1 lec-rec.
Optimization techniques involving nonlinear functions. Stress is on solution methods such as one-dimensional search, steepest-descent and second-order methods for unconstrained optimization; penalty, barrier, cutting-plane and feasible-direction methods for constrained optimization.

435 Introduction to Game Theory Fall. 3 credits.
3 lecs.
A broad survey of the mathematical theory of games, including such topics as two-person matrix and bimatrix games; cooperative and noncooperative n-person games; games in extensive, normal, and characteristic function form. Economic market games. Structure theory for games arising from complex organizations.

[462 Introductory Engineering Stochastic Processes II Fall. 4 credits. Not offered 80–81. Prerequisite: OR&IE 361 or equivalent.
3 lecs, 1 rec.
A selection of topics from the following: Time series, Markov and semi-Markov processes, optimal stopping; examples and applications are drawn from several areas.]

471 Applications of Statistics to Engineering Problems Fall. 4 credits. Prerequisite: OR&IE 370 or equivalent.
3 lecs, 1 rec.
Sample size calculations for one- and two-sample tests; theory of multiple linear regression and applications to problems in engineering and the sciences, including graphic and analytic techniques useful in model building; analysis of data from experiments with qualitative factors including one-way and two-way Anova models. Use of the computer as a tool for statistics is stressed.

472 Statistical Decision Theory Spring. 3 credits. Prerequisite: OR&IE 471 or equivalent.
3 lecs.
Same topics as OR&IE 672, with emphasis on applications in sampling inspection, inventory control, estimation of parameters, testing hypotheses.

516 Mathematical Models — Development and Application Fall. 4 credits. Prerequisites: OR&IE 320 and 361 or permission.
4 rec-labs.
A laboratory course concerned with structuring problems and operational systems as mathematical models. A sequence of situations for which students must construct representative models is considered. Models are examined for their usefulness in analysis, synthesis, and design.

519 Industrial Engineering Fieldwork Fall or spring. Credit to be arranged. Prerequisite: permission of instructor.
Project-type work, under faculty supervision, on a real problem existing within some firm or institution, usually a regional organization. Opportunities in the course may be discussed with the associate director.

551 Advanced Engineering Economic Analysis Spring. 4 credits. Prerequisites: OR&IE 350 and knowledge of linear programming and statistics, or permission of instructor.
3 lecs, 1 rec.
The economics of production. Topics concerning economic decision making at the level of the firm include long-range planning, budgeting and control, and project investment decisions under certainty and uncertainty. Topics in industrial economics include productivity, technical change, and industrial development.

561 Queueing Theory and Its Applications Fall. 3 credits. Prerequisite: OR&IE 361 or permission.
3 lecs.
Basic queueing models. Design and control of queueing systems. Statistical inference from queueing processes. Solution techniques (including simulation). Scheduling and equipment maintenance. Highway and urban traffic networks. Analysis of computer systems.

562 Inventory Theory Fall. 4 credits. Prerequisite: OR&IE 320 and 361.
3 lecs, 1 rec.
Discussion of the nature of inventory systems and their design and control. Periodic and continuous review policies for single-item and single-location problems. Multi-item and multi-echelon extensions. Dynamic and static models are discussed. Redistribution methods are analyzed. Applications are stressed.

[563 Applied Time Series Analysis Fall. 3 credits. Prerequisite: OR&IE 361, Computer Science 211, or permission of instructor. Not offered 1980–81.
2 lecs, 1 rec; final project.
Box-Jenkins models, which are versatile, widely used, and applicable to nonstationary and seasonal time series, are covered in detail. The various stages of model identification, estimation, diagnostic checking, and forecasting are treated. Long-range dependence models and the related statistics are considered. As time permits, other topics such as spectral analysis, filtering, the sampling and aliasing problem, and the fast Fourier transform algorithm will be discussed. Applications to economics and hydrology are emphasized. Assignments require computer work.]

[570 Statistical Methods in Quality and Reliability Control Spring. 3 credits. Prerequisite: OR&IE 370 or equivalent. Not offered 1980–81.
3 lecs.
Control concepts and methods for attributes and variables; process capability analysis; acceptance sampling plans; elementary procedures for variables; acceptance-rectification procedures. Reliability concepts; exponential and normal distributions in reliability; life and reliability analysis of components and systems; redundancy.]

599 Project Fall and spring. 5 credits. For M.Eng. students.
Identification, analysis, design, and evaluation of feasible solutions to some applied problem within the OR&IE field. A formal report and oral defense of the approach and solution are required.

[614 Facilities Location and Design Spring. 3 credits. Prerequisite: OR&IE 320 or 622 or permission of instructor. Not offered 1980–81.
3 lec-recs.
Formulation, analysis, and solution techniques for location and facility design problems. Applications in industrial, environmental, and regional areas.]

622 Operations Research I Fall. 3 credits. Not open to students who have had OR&IE 320.
3 lec-recs.
Survey of deterministic models. Models are drawn from linear, mixed-integer, nonlinear, and dynamic programming. Network theory, game theory, and deterministic inventory models. Modeling and applications are stressed.

623 Operations Research II Spring. 3 credits. Not open to students who have had OR&IE 361. Prerequisite: OR&IE 260 or 270 or permission of instructor.
3 lec-recs.
Models of inventory and production control. Markov decision models, queueing theory and its applications. Simulation. Illustrative examples and problems.

[625 Scheduling Theory Spring. 3 credits. Prerequisite: permission of instructor. Not offered 1980–81.
3 lec-recs.
Scheduling and sequencing problems. Single resource scheduling, parallel processing, flow shop scheduling. Methodology is drawn from dynamic and integer programming; simulation techniques and heuristic methods.]

[626 Advanced Production and Inventory Planning Spring. 3 credits. Not offered 1980–81.
3 lecs.
Introduction to a variety of production and distribution planning problems; the development of mathematical models corresponding to these problems; a study of approaches for finding solutions.]

630–631 Mathematical Programming I and II 630, fall; 631, spring. 3 credits each term. Prerequisite: advanced calculus.
3 lecs.
A rigorous treatment of the theory and computational techniques of linear programming and its extensions. Formulation, duality theory, simplex, and dual simplex methods. Sensitivity analysis. Network flow problems and algorithms. Theory of polyhedral convex sets, systems of linear equations and inequalities, Farkas' Lemma. Exploiting special structure in the simplex method, computational implementation. Decomposition Principle. Introduction to integer and nonlinear programming and game theory.

[632 Nonlinear Programming Fall. 3 credits. Prerequisite: OR&IE 630. Not offered 1980–81.
3 lecs.
Necessary and sufficient conditions for unconstrained and constrained optima. Computational methods, including interior (e.g., penalty functions), boundary (e.g., gradient projection), and exterior (e.g., cutting plane) approaches.]

635 Game Theory I Fall. 3 credits. Prerequisite: Mathematics 411 or permission of instructor.
3 lecs.
The minimax theorem for two-person zero-sum games. Two-person general sum games and noncooperative n-person games; Nash equilibrium points. Cooperative n-person games; the core, stable sets, Shapley value, bargaining set, kernel, nucleolus.

637 Dynamic Programming Spring. 3 credits. Prerequisite: concurrent registration in OR&IE 660 and Mathematics 411 or equivalent.
3 lecs.
Optimization of sequential decision processes. Deterministic and stochastic models, infinite horizon Markov decision models, policy iterations. Contraction mapping methods. Applications drawn from inventory theory, production control; discrete combination examples.

639 Convex Analysis Fall. 3 credits. Prerequisite: Mathematics 411 and 431 or permission of instructor.
3 lecs.
The theory of finite dimensional convex sets is developed through the study of real valued convex functions and Fenchel duality. Separation of convex sets, polarity correspondences, recession cones, theorems of Helly and Caratheodory.

[641 Integer Programming Spring. 3 credits. Prerequisite: OR&IE 630. Not offered 1980–81.
3 lecs.
Discrete optimization. Linear programming in which the variables are restricted to be integer-valued. Theory, algorithms, and applications. Cutting plane methods, enumerative methods, and group theoretic methods; additional topics are drawn from recent research in this area.]

643 Graph Theory and Network Flows Fall. 3 credits. Prerequisite: permission of instructor.
3 lecs.
Directed and undirected graphs. Bipartite graphs. Hamilton cycles and Euler tours. Connectedness, matching, and coloring. Flows in capacity-constrained networks. Maximum flow and minimum cost flow problems.

644 Combinatorial Optimization Spring. 3 credits. Prerequisite: permission of instructor.
3 lecs.
Topics in combinatorics, graphs, and networks. These include matching, matroids, polyhedral combinatorics, and optimization algorithms.

660 Applied Probability Fall. 4 credits. Prerequisite: advanced calculus.
3 lecs, 1 rec.
Introduction to basic probability. The sample space; events; probability. Conditional probability. Independence. Product spaces. Random variables. Important distributions. Characteristic functions. Convergence concepts. Limit theorems.

661 Applied Stochastic Processes Spring. 4 credits. Prerequisite: OR&IE 660 or equivalent.
3 lecs, 1 rec.
An introduction to stochastic processes that presents the basic theory together with a variety of applications. Topics include Markov processes, renewal theory, random walks, branching processes, Brownian motion, stationary processes.

670 Applied Statistics Spring. 4 credits. Prerequisite: OR&IE 660 or equivalent.
3 lecs, 1 rec.
Review of distribution theory of special interest in statistics: normal, chi-square, binomial, Poisson, t, and F; introduction to statistical decision theory; sufficient statistics; theory of minimum variance unbiased point estimation; maximum likelihood and Bayes estimation; basic principles of hypothesis testing, including Neyman-Pearson lemma and likelihood ratio principle; confidence interval construction.

671 Intermediate Applied Statistics Fall. 4 credits. Prerequisite: OR&IE 670 or equivalent.
3 lecs, 1 rec.
Statistical inference based on the general linear model; least squares estimators and their optimality properties; likelihood ratio tests and corresponding confidence regions; simultaneous inference. Applications in regression analysis and ANOVA models. Variance components and mixed models. Correlation, ridge regression. Use of the computer as a tool for statistics is stressed.

[672 Statistical Decision Theory Fall. 3 credits. Prerequisite: OR&IE 471 or 670 or equivalent. Not offered 1980–81.
3 lecs.
The general problem of statistical decision theory and its applications. Comparison of decision rules; Bayes, admissible, and minimax rules. Problems involving sequences of decisions over time. Use of the sample cdf and other simple nonparametric methods. Applications.]

[673 Nonparametric Statistical Analysis Spring. 3 credits. Prerequisite: OR&IE 670 or permission. Not offered 1980–81.
3 lecs.
Estimation of quantiles, cdf's, and pdf's. Properties of order statistics and rank-order statistics. Hypothesis testing in one- and several-sample situations; sign tests; use of ranks for tests and estimation. Small and large sample properties of tests. Asymptotic distributions of test statistics. Testing goodness of fit.]

[674 Design of Experiments Spring. 4 credits. Prerequisite: OR&IE 671 or permission. Not offered 1980–81.
3 lecs.
Use and analysis of experimental designs such as randomized blocks and Latin squares; analysis of variance and covariance, factorial experiments; statistical problems associated with finding best operating conditions; response-surface analysis.]

675 Qualitative Data Analysis Spring. 3 credits. Prerequisite: OR&IE 671.
Varieties of categorical data; cross classifications and contingency tables; tests for independence; multidimensional tables and log-linear models maximum likelihood and weighted least squares estimation; tests of goodness of fit; analysis of incomplete tables; life tables; paired comparison experiments.

676 Statistical Analysis of Life Data Fall. 3 credits. Prerequisite: OR&IE 671 or equivalent.
Analysis of data from reliability, fatigue, and life-testing studies in engineering; also biomedical applications. Survival distributions, hazard rate, censoring. Life tables. Estimation and hypothesis testing. Standards. Goodness of fit, hazard plotting. Covariance analysis, accelerated life testing. Multiple decrement models, competing risks. Sample size determination. Adaptive sampling.

680 Digital Systems Simulation Fall. 4 credits. Prerequisites: Computer Science 211 and OR&IE 370 or permission of instructor.
2 lecs, 1 rec.
Digital computer programs to simulate the operation of complex discrete systems in time. Modeling, program organization, random number and deviate generation, simulation languages, statistical considerations; applications to a variety of problem areas.

729 Selected Topics in Applied Operations Research Fall or spring. Credit to be arranged.
Current research topics dealing with applications of operations research.

736 Game Theory II Spring. 3 credits. Prerequisite: OR&IE 635.
3 lecs.
A continuation of OR&IE 635, including in-depth treatment of some of the same topics plus such additional topics as games in extensive form, games without side payments, economic market games, and games with infinitely many players.

738 Selected Topics in Game Theory Fall or spring. Credit to be arranged.
Current research topics in game theory.

739 Selected Topics in Mathematical Programming Fall or spring. Credit to be arranged.
Current research topics in mathematical programming.

[752 Advanced Inventory Control Spring. 3 credits. Prerequisite: permission of instructor. Not offered 1980–81.
3 lecs.
The theoretical foundation of inventory theory. Both single-item, single-location problems and multi-item, multi-echelon inventory systems are analyzed. Topics covered include a study of static and dynamic (s,S) policies under a variety of assumptions concerning the demand process and system structure as well as computational techniques.]

[761 Advanced Queueing Theory Fall. 3 credits. Prerequisite: OR&IE 660 or equivalent. Not offered 1980–81.
3 lecs.
A study of stochastic processes arising in a class of problems including congestion, storage, dams, and insurance. The treatment will be self-contained. Transient behavior of the processes is emphasized. Heavy traffic situations are investigated.]

762 Advanced Stochastic Processes Fall. 3 credits. Prerequisite: OR&IE 661 or equivalent.
3 lecs.

A selection of topics from the following: stationary processes, Levy processes, diffusion processes, point processes, martingales, regenerative phenomena, stochastic calculus, weak convergence.

[764 Deterministic and Stochastic Control Spring. 3 credits. Prerequisite: OR&IE 661 or equivalent. Not offered 1980–81.
3 lecs.
Topics include: elements of calculus of variations, Pontryagin's maximum principle, Markov decision processes, dynamic programming. Problems in filtering and prediction, production planning and inventory control, congestion phenomena, storage models, and environmental management are discussed.]

769 Selected Topics in Applied Probability Fall or spring. Credit arranged.
Topics are chosen from current literature and research areas of the staff.

[773 Statistical Selection and Ranking Procedures Spring. 3 credits. Prerequisite: OR&IE 674 or permission. Not offered 1980–81.
3 lecs.
A study of multiple-decision problems in which a choice must be made among two or more courses of action. Major emphasis is on selection and ranking problems involving choosing the "best" category where goodness is measured in terms of a particular parameter of interest. Statistical formulations of such problems: indifference-zone, subset, and other approaches. Single-stage, two-stage, and sequential procedures. Applications. Recent developments.]

779 Selected Topics in Applied Statistics Fall or spring. Credit to be arranged.
Topics chosen from current literature and research interests of the staff.

790 Special Investigations Fall or spring. Credit arranged. For individuals or small groups.
Study of special topics or problems.

891 Operations Research Graduate Colloquium Fall or spring. 1 credit.
A weekly 1½-hour meeting devoted to presentations by distinguished visitors, by faculty members, and by advanced graduate students, on topics of current research in the field of operations research.

893–894 Applied OR&IE Colloquium 893, fall; 894, spring. 1 credit each term.
A weekly meeting of M.Eng. students. Discussion of assigned topics; presentations by practitioners in the field.

Theoretical and Applied Mechanics

Basics in Engineering Mathematics and Mechanics

202 Mechanics of Solids Fall or spring. 3 credits.
Prerequisite: coregistration in Mathematics 293.
2 lecs, 1 rec, 4 labs each semester; evening exams.
See description under Division of Basic Studies.

203 Dynamics Fall or spring. 3 credits.
Prerequisites: coregistration in Mathematics 294.
2 lecs, 1 rec, 4 labs each semester; evening exams.
See description under Division of Basic Studies.

293 Engineering Mathematics (also Mathematics 293) Fall or spring. 3 credits. Prerequisite: Mathematics 192 or 194.
Evening exams (see Mathematics 293).
Infinite series, complex numbers, first and second order ordinary differential equations with applications in the physical and engineering sciences.

294 Engineering Mathematics (also Mathematics 294) Fall and spring. 4 credits. Prerequisite: Mathematics 293.
Evening exams (see Mathematics 294).
Vector spaces and linear algebra, matrices, eigenvalue problems and applications to systems of linear differential equations. Vector calculus. Boundary value problems and introduction to Fourier series.

Engineering Mathematics

310 Advanced Engineering Analysis I Fall and spring. 3 credits. Prerequisite: Mathematics 294 or equivalent.
3 lecs.
Ordinary differential equations as applied in engineering context. Analytical and numerical methods. Special functions, initial value,boundary value and eigenvalue problems in linear partial differential equations, introduction to nonlinear ordinary differential equations.

311 Advanced Engineering Analysis II Spring. 3 credits. Prerequisite: T&AM 310 or equivalent.
Functions of several variables, introduction to complex variables, analytic functions, conformal mapping, method of residues. Application to the solution of Laplace's equation, and transform inversion techniques. Examples drawn from fluid mechanics, heat transfer, electromagnetics, and elasticity.

610 Methods of Applied Mathematics I Fall. 3 credits. Intended for beginning graduate students in engineering and science who have a heterogeneous mathematical background. An intensive course, requiring more time than is normally available to undergraduates (see T&AM 310–311), but open to exceptional undergraduates with permission of instructor.
3 lecs.
Emphasis is on applications. Linear algebra; calculus of several variables; vector analysis; series; ordinary differential equations; complex variables.

611 Methods of Applied Mathematics II Spring. 3 credits. Prerequisite: T&AM 610 or equivalent.
3 lecs.
Emphasis on applications. Partial differential equations; tensor analysis; calculus of variations.

613 Methods of Applied Mathematics IIIa Fall. 2 credits. Prerequisite: T&AM 611 or equivalent. First of an 8-credit sequence (T&AM 613, 614, 615, 616) that develops advanced mathematical techniques for engineering problems.
Review of complex variable theory; conformal mapping; complex integral calculus. Nonlinear partial differential equations; general theory of characteristics.

614 Methods of Applied Mathematics IIIb Spring. 2 credits. Prerequisite: 613 or equivalent.
Integral transforms for partial differential equations. Green's function; asymptotics, including steepest descent and stationary phase, Wiener-Hopf technique. Problems drawn from vibrations and acoustics, fluid mechanics and elasticity, heat transfer, and electromagnetics.

615 Methods of Applied Mathematics IVa Fall. 2 credits. Prerequisite: T&AM 611 or equivalent.
In context of applications: regular and singular perturbation theory, method of matched asymptotic expansions, two timing (method of multiple scales), WKB approximation.

616 Methods of Applied Mathematics IVb Spring. 2 credits. Prerequisite: concurrent registration in T&AM 614 or equivalent.
In context of applications: Hilbert-Schmidt and Fredholm theories of integral equations, Wiener-Hopf equations with application to finite interval, Carleman equation and its generalization, effective approximations.

Experimental Mechanics

640 Experimental Mechanics Fall. 3 credits.
1 lec.
Each student is expected to perform six to ten experiments in mechanics, selected to meet his or her individual interests. Topics: elastic viscoelastic, microplastic, and plastic response of materials; linear and nonlinear vibration of discrete and continuous systems; acoustic and elastic wave propagation and scattering phenomena; dynamical stability of rigid bodies; analog and digital simulation of dynamical systems; magnetoelastic interactions.

Continuum Mechanics and Inelasticity

450 Introduction to Continuum Mechanics Fall. Offered alternate years. 3 credits.
Provides a foundation for further studies in fluid and solid mechanics, materials science, and other branches of engineering. Vector and tensor analysis; kinematics of deformation; analysis of stress and strains; balance laws of physics; constitutive equations; examples of elasticity and fluid mechanics.

[651 Continuum Mechanics and Thermodynamics Fall. 3 credits. Offered alternate years. Not offered 1980–81.
Kinematics; conservation laws; the entropy inequality; constitutive equations; frame indifference; material symmetry. Simple materials and the position of classical theories in the framework of modern continuum mechanics.]

[752 Topics in Continuum Mechanics Spring. 3 credits. Prerequisite: T&AM 651. Offered alternate years. Not offered 1980–81.
Theory of (nonlinear) elasticity and thermoelasticity; universal solutions, wave propagations, and stability theory. Nonlinear viscoelastic fluids and solids. Viscometric flows. Materials with continuum microstructure.]

754 Analytical Methods in Continuum Mechanics Spring. 3 credits. Prerequisite: permission of instructor. Offered alternate years.
Tensor analysis with applications to shell theory, incompatibility, and finite elasticity. Calculus of variations. Group theoretical methods in solid and fluid mechanics. Noether's theorem. Conservation laws.

[757 Viscoelasticity and Creep Fall. 3 credits. Offered alternate years. Not offered 1980–81.
Linear viscoelasticity: constitutive equations, models, differential and integral operators, Laplace transforms, complex modulus, vibrations and wave propagation, boundary value problems. Thermoviscoelasticity. Creep: classical and modern theories, stress redistribution, boundary value problems.]

758 Theory of Plasticity Fall. Offered alternate years. 3 credits.
Plastic stress-strain laws, yield criteria, flow rules. Work hardening. Flexure and torsion of bars. Boundary-value problems — thick cylinders, spheres, discs, general 3-D. Residual stress. Limit analysis of structures. Plane strain — slip line theory.

Elasticity and Waves

663 Applied Elasticity Fall. 3 credits. Two 1½-hour lec.
Thin curved bars. Plane stress and strain in cylinders; effects of pressure, rotation, and thermal stress. Small (and large) deflection theory of plates; classical, approximate, and strain-energy methods. Thin cylindrical shells. A first course in elastic deformable bodies with numerous engineering applications.

664 Theory of Elasticity Spring. 3 credits.
Two 1½-hour lec.
Analysis of stress and strain. Airy's stress function solutions using Fourier series and integrals. Torsion theory. Three-dimensional solutions. Bending of prismatical bars. Axially loaded circular cylinder and half space. All topics are illustrated by engineering applications.

666 Fundamentals of Acoustics (also Electrical Engineering 690) Spring. 3 credits.
3 lecs, biweekly labs.
Introduction to the principles and theories of acoustics. The vibrations of strings, bars, membranes, and plates; plane and spherical acoustic waves; transmission phenomena; resonators and filters; waves in solids and fluids. Application is made to sonic and ultrasonic transducers, music and noise, and architectural acoustics, and an introduction is given to the processing of acoustic signals. At the level of *Fundamentals of Acoustics* by Kinster and Frey.

667 Mechanical Vibrations and Waves Fall. 3 credits.
Two 1½-hour lec, 4 labs each semester.
Review of vibrations of discrete systems, including multi-degree-of-freedom vibrations, forced oscillations, determination of natural modes and frequencies. Unified treatment of vibrations and wave phenomena in continuous elastic systems including strings, rods, beams, membranes, and plates. Approximate methods for finding natural modes and frequencies. Calculation of wave speeds, dispersion, and group velocity. Plane, cylindrical, and spherical waves. Transient response of discrete and continuous systems.

[765 Mathematical Theory of Elasticity Spring. Offered alternate years. 3 credits. Prerequisite: T&AM 664. Not offered 1980–81.
The basic equations of large-deformation elasticity; solution of certain large-deformation problems. Linearization. Boussinesq-Papkovich potentials and three-dimensional problems; plane stress by method of Muskhelishvili; conformal mapping; torsion problems.]

[768 Elastic Waves in Solids Fall. 3 credits. Two 1½-hour lec. Offered alternate years. Not offered 1980–81.
An advanced course on dynamic stress analysis and wave propagation in elastic solids. Theory of elastodynamics. Waves in isotropic and anisotropic media. Reflection and refraction. Surface waves and waves in layered media. Transient waves and methods of Lamb-Cagniard-Pekeris. Thick plate theories. Vibration of spheres. Scattering of waves and dynamic stress concentration.]

Dynamics and Space Mechanics

670 Intermediate Dynamics Fall. 3 credits. Two 1¼-hour lec.
Newtonian mechanics for single particles and systems of particles, conservation laws, central-force motion; special relativity; Eulerian mechanics for rigid bodies, tops, gyroscopes; generalized coordinates, D'Alembert's principle, Lagrangian equations, analytic mechanics for particles and rigid bodies.

[672 Celestial Mechanics (also Astronomy 579) Spring. 3 credits. Two 1¼-hour lec. Offered alternate years. Not offered 1980–81.
Description of orbits; 2-body, 3-body and n-body problems; Hill curves, libration points and their stability; capture problems; virial theorem. Osculating elements, perturbation equations: effects of gravitational potentials, atmospheric drag, and solar radiation forces on satellite orbits; secular perturbations, resonances.]

673 Mechanics of the Solar System (also Astronomy 571) Spring. 3 credits. Prerequisite: an undergraduate course in dynamics.
Two 1¼-hour lec.
Gravitational potentials, planetary gravity fields. Free and forced rotations, Chandler wobble, polar wander, damping of nutation. Equilibrium tidal theory, tidal heating. Orbital evolution of natural satellites, resonances, spin-oribt coupling, Cassini states. Long-term variations in planetary orbits. Dust dynamics. Dynamics of ring systems. Physics of interiors, seismic waves, free oscillations. Illustrative examples are drawn from contemporary research.

771 Advanced Dynamics Fall. 3 credits. Prerequisite: T&AM 670 or equivalent. Offered alternate years.
Review of Lagrangian mechanics; Hamilton's principle, the principle of least action, and related topics from the calculus of variations; Hamilton's canonical equations; approximate methods for two-degrees-of-freedom systems (Birkhoff's transformation); canonical transformations and Hamilton-Jacobi theory; Poisson stability and related topics from topological dynamics; Hamilton's principle for continuous systems, applications to shell dynamics.

[775 Nonlinear Vibrations Fall. 3 credits. Prerequisite: T&AM 667 or equivalent. Offered alternate years. Not offered 1980–81.
Review of linear systems, free and forced vibrations. Nonlinear systems, phase plane methods, method of isoclines. Conservative systems. General autonomous systems, equilibrium and periodic solutions, linearization and Lyapunov stability criteria, Poincare-Bendixson theorem, indices. Quantitative analysis of weakly nonlinear systems in free and forced vibrations, perturbation methods, Krylov-Bogoliubov method. Applications to problems in mechanics.]

776 Stability of Motion Spring. 3 credits. Offered alternate years.
3 lecs.
Definitions of Lagrange, Lyapunov, and orbital stability; invariance of these definitions under a change of coordinates; linearized variational equations: Jordan canonical form, Floquet theory, perturbations, Mathieu's equation, Lyapunov's theory of types; nonlinear variational equations: Lyapunov's direct method, validity of the linearized variational equations.

777 Qualitative Theory of Dynamical Systems Fall. 3 credits. Prerequisite: T&AM 775 or equivalent. Offered alternate years.
Review of planar (single degree-of-freedom) systems. The concept of dynamical systems, local and global analysis. N-dimensional systems, types of solutions, Poincaré maps, stability. Structural stability and generic properties, bifurcations in planar systems. Discrete dynamical systems, maps and difference equations, homoclinic and heteroclinic motions, the Smale Horseshoe and other complex invariant sets. Implications for systems of dimension greater than 3, strange attractors and chaos in free and forced oscillator equations.

Special Courses, Projects, and Thesis Research

491–492 Project in Engineering Science 491, fall; 492, spring. 1 to 4 credits, as arranged.
Projects for undergraduates under the guidance of a faculty member.

798–799 Selected Topics in Theoretical and Applied Mechanics 798, fall; 799, spring. 1–4 credits, as arranged.
Special lectures or seminars on subjects of current interest. Topics are announced when the course is offered.

890–990 Research in Theoretical and Applied Mechanics Fall or spring. 1–6 credits; 890: 1–9 credits; 990: as arranged.
Thesis or independent research at the M.S. (890) or Ph.D. (990) level on a subject of theoretical and applied mechanics. Research is under the guidance of a faculty member.