Courses

Course Numbers

This section has been prepared to give you a listing and description of the approved graduate level courses at the University of Missouri-Rolla. Courses listed are those approved at the time this publication went to press. Changes are made at regular intervals. Electronic catalog descriptions, which are updated during the academic year, are available on the Web at www.umr.edu/~regwww. This will enable you to keep abreast of new course additions. For current information on when courses are available, consult the campus schedule of classes available from the Registrar's Office, 103 Parker Hall.

0- 99 Courses normally taken by freshman and sophomores. May not be used as any part of a graduate degree program.

100-199 Courses normally taken by upper-class undergraduate students. May not be used as any part of a graduate degree program.

200-299 Upper-class undergraduates and restricted graduate courses. Courses so numbered do not give graduate credit for an advanced degree in the field of the department offering the course.

300-399 Upper-class undergraduates and graduate students. Commonly approved for graduate programs only when the student is regularly enrolled in a graduate school and then only if the course fits the purpose of the degree program.

400-499 Graduate courses and research. Undergraduate and postbaccalaureate students are not normally eligible to enroll in 400-level courses.

Course Information

The number in parentheses following the name of the course indicates the number of credit hours given for successfully completing the course. It also reflects the section type; for example, **(Lect 3.0)** designates a lecture course of three hours credit; **(Lab 1.0)** designates a laboratory course of one hour credit. A lecture credit hour is usually the credit granted for satisfactorily passing a course of approximately 15 classroom hours. A laboratory course of one hour credit would normally meet one classroom hour per week for 15 weeks.

Three credit hour courses normally meet during a 50 minute class period, three times per week, for 15 weeks. For flexible scheduling, some sections of a course are scheduled to meet for 75 minutes, twice a week. The class time is the same in each case. If you have two classes in succession, there will normally be at least 10 minutes between classes. Classes normally begin on the half-hour and end 20 minutes past the hour.

Students must have completed the stated prerequisite(s) for the course for admission to the course or obtain the 'Consent of the Instructor' of the course.

AEROSPACE ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

307 Vibrations I (Lect 3.0) Equations of motion, free and forced vibration of single degree of freedom systems. Natural frequencies, resonance, modes of vibration and energy dissipation are studied. The vibration of continuous systems is introduced. Prerequisites: Mc Eng 211 and 213, or Ae Eng 213 and Math 204. (Co-listed with Mc Eng 307, E Mech 361)

309 Engineering Acoustics I (Lect 3.0) Introduction to acoustical theory and measurement with emphasis on mechanical and aerospace engineering applications. Plane and spherical wave propagation, resonators and filters, absorption, room acoustics, human response to noise, noise legislation, noise control. Use of common instrumentation in several projects. Prerequisites: Mc Eng 211 & 213, or Ae Eng 213 & Math 204. (Co-listed with Mc Eng 309)

311 Introduction to Composite Materials & Structures (Lect 3.0) Introduction to fiber-reinforced composite materials and structures with emphasis on analysis and design. Composite micromechanics, lamination theory and failure criteria. Design procedures for structures made of composite materials. An overview of fabrication and experimental characterization. Prerequisite: Bas En 110. (Co-listed with E Mech 381 and Mc Eng 382)

313 Intermediate Dynamics of Mechanical and Aerospace Systems (Lect 3.0) Principles of dynamics are applied to problems in the design of mechanical and aerospace systems; basic concepts in kinematics and dynamics; dynamics of systems of particles; dynamics of rigid bodies, three-dimensional effects in machine elements; dynamic stability, theory and applications; methods of analytical dynamics. Prerequisite: MC Eng 213 or AE Eng 213. (Co-listed with MC Eng 313)

314 Spaceflight Mechanics (Lect 3.0) Further topics in orbital mechanics. Time equations, Lambert's problem, patched-conic method, orbital maneuvers, orbit determination, orbit design, reentry problem. Prerequisite: AE Eng 213.

315 Concurrent Engineering I (Lect 3.0) Students will be introduced to the concurrent engineering approach to product development. They will learn to set up quantitative requirements and then use a quantitative rating process to identify the critical requirements relating to the desired product. The interaction between design, manufacturing, assembly, cost, and supportability will be covered. The students will form teams and practice the concurrent engineering process for simple products. Prerequisites: Mc Eng 213 or Ae Eng 231, and Bas En 110. (Co-listed with Mc Eng 315)

316 Concurrent Engineering II (Lab 3.0) Students will form groups and then using the electronic data based approach apply the concurrent engineering process to develop products. Areas to be covered are the customer, design, manufacturing, assembly, cost and supportability. Prerequisite: Ae Eng 315 or Mc Eng 315. (Co-listed with Mc Eng 316)

319 Advanced Thermodynamics (Lect 3.0) After a short review of classical thermodynamics, the elements of chemical reactions, chemical equilibrium, statistical thermodynamics, and the basic concepts of kinetic theory are presented. Prerequisite: Ae Eng 233. (Co-listed with Mc Eng 319)

321 Aerodynamics CAD design (Lab 3.0) Aircraft fuselages, wings, and fuselage-wing configurations will be constructed with a 3D CAD package, UNIGRAPHICS. These configurations will then be analyzed with an aerodynamics paneling program. Emphasis will be placed on the designing of these shapes for maximizing the aerodynamic performance. Prerequisite: Ae Eng 231.

322 Introduction to Solid Mechanics (Lect 3.0) Review of basic concepts in continuum mechanics. Finite elasticity: some universal solutions for isotropic materials, application of special mechanical models. Linear elasticity: compatibility, stress functions, superposition, special examples such as extension, torsion, bending, and plane problems. Elements of plasticity. Prerequisite: E Mech 311. (Co-listed with E Mech 322, Mc Eng 322)

325 Intermediate Heat Transfer (Lect 3.0) Analytical study of conduction; theory of thermal radiation and applications; energy and momentum equations in convective heat transfer and review of empirical relations. Current topics are included. Prerequisite: Mc Eng 225. (Co-listed with Mc Eng 325)

327 Theory of Combustion (Lect 3.0) Application of chemical, thermodynamic, and gas dynamic principles to the combustion of solid, liquid, and gaseous fuels. Includes stoichiometry, thermochemistry, reaction mechanism, reaction velocity, temperature levels, and combustion waves. Prerequisite: Mc Eng 221. (Co-listed with Mc Eng 327)

329 Smart Materials and Sensors (Lect 2.0 and Lab 1.0) Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multi-disciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 204. (Co-listed with Mc Eng, E Mech, El Eng 329 and Cv Eng 318)

331 Thermofluid Mechanics II (Lect 3.0) Derivation of Navier-Stokes equations, exact solutions of some simple flows. Superposition methods for in-

viscid flows. Intermediate treatment of boundary layer theory, and gas dynamics. Introduction to turbulence and kinetic theory. Prerequisite: Mc Eng 231 or Ae Eng 231. (Co-listed with Mc Eng 331)

334 Theory of Stability I (Lect 3.0) Formulation of stability concepts associated with columns, beams, and frames. Applications to some engineering problems utilizing numerical methods. Prerequisites: Bas En 110; Math 204 & either Bas En 150 or E Mech 160. (Co-listed with Mc Eng 334, E Mech 334)

335 Aerospace Propulsion Systems (Lect 3.0) Study of atmospheric and space propulsion systems with emphasis on topics of particular current interest. Mission analysis in space as it affects the propulsion system. Power generation in space including direct and indirect energy conversion schemes. Prerequisite: Ae Eng 235.

336 Fracture Mechanics (Lect 3.0) Linear elastic and plastic mathematical models for stresses around cracks; concept of stress intensity; strain energy release rates; correlation of models with experiment; determination of plane stress and plane strain parameters; application to design. Prerequisite: Bas En 110. (Co-listed with Mc Eng 336, E Mech 336)

339 Computational Fluid Mechanics (Lect 3.0) Introduction to the numerical solution of the Navier-Stokes equations, by finite difference methods, in both stream function-vorticity and primitive variable formulations. Course format emphasizes student development of complete computer programs utilizing a variety of solution methods. Prerequisites: Cmp Sc 73, one course in fluid mechanics. (Co-listed with Mc Eng 339)

341 Experimental Stress Analysis I (Lect 2.0 and Lab 1.0) Acquaints the student with some techniques of experimental stress analysis. Principal stresses, strain to stress conversion, mechanical and optical strain gages, electrical resistance strain gages, transducers, and brittle coatings. Prerequisite: Bas En 110. (Co-listed with Mc Eng 341, E Mech 341)

342 Experimental Stress Analysis II (Lect 2.0 and Lab 1.0) Acquaints the student with some techniques of experimental stress analysis. Topics include principal stresses, strain to stress conversion, transmission and reflection photoelastic methods, Moire fringe methods, and analogies. Prerequisites: Bas En 110, E Mech 321. (Co-listed with Mc Eng 342, E Mech 342)

343 **Photographic Systems for Engineering Applications** (Lect 2.0 and Lab 1.0) Study of photographic techniques applied to engineering uses including observations of events, recording and storage of data, and communication and dissemination of information. Both conventional and special photo-optical systems are covered. Prerequisite: Senior standing. (Co-listed with Mc Eng 343)

344 Fatigue Analysis (Lect 3.0) The mechanism of fatigue, fatigue strength of metals, fracture mechanics, influence of stress conditions on fatigue strength, stress concentrations, surface treatment effects, corrosion fatigue and fretting corrosion, fatigue of joints components and structures, design to prevent fatigue. Prerequisite: Bas En 110. (Co-listed with E Mech 337, Mc Eng 338)

349 Robotic Manipulators & Mechanisms (Lect 2.0 and Lab 1.0) Overview of industrial applications, manipulator systems and geometry. Manipulator kinematics; hand location, velocity and acceleration. Basic formulation of manipulator dynamics and control. Introduction to machine vision. Projects include robot programming, vision-aided inspection and guidance, and system integration. Prerequisites: Cmp Sc 73, Ae Eng 213. (Co-listed with Mc Eng 349)

350 Integrated Product Development (Lect 2.0 and Lab 1.0) Students in design teams will simulate the industrial concurrent engineering development process. Areas covered will be design, manufacturing, assembly, cost, and product support. Using a 3-D solid modeling program, students will design, analyze, and send the data base to the automated machine shop where the parts will be manufactured. The parts will then be assembled, tested and analyzed for their performance. Prerequisites: Ae Eng 251 or Mc Eng 208 for Design; Mc Eng 213 for Assembly; Accompanied or preceded by Mc Eng 353 for Manufacturing; Eng Mg 375 or 385 for Cost/Product Support. (Co-listed with Mc Eng 350 and Eng Mg 350)

351 Intermediate Aerospace Structures (Lect 3.0) Discussion of the finite element method for static and dynamic analysis of complex aerospace structures. Solution of basic problems using established finite element computer programs. Prerequisite: Ae Eng 253 or Mc Eng 212. (Co-listed with Mc Eng 351)

352 Finite Element Approximation I—An Introduction (Lect 3.0) Variational statement of a problem. Galerkin Approximation, finite element basis functions and calculations, element assembly, solution of equations boundary conditions, interpretation of the approximation solution, development of a finite element program, two-dimensional problems. Prerequisite: Math 204. (Co-listed with Mc Eng 312, E Mech 307)

353 Aeroelasticity (Lect 3.0) Study of phenomena involving interactions among inertial, aerodynamic, and elastic forces and the influence of these interactions on aircraft and space vehicle design. Some aeroelastic phenomena are: divergence, control effectiveness, control reversal, flutter, buffeting, dynamic response to rapidly applied loads, aeroelastic effects on load distribution, and static and dynamic stability. Prerequisites: Ae Eng 251 and 271.

361 Flight Dynamics-Stability and Control (Lect 3.0) Review of static stability, dynamic equations of motion, linearized solutions, classical control design and analysis techniques, introduction to modern control. Prerequisite: Ae Eng 261.

362 Experimental Vibration Analysis (Lect 2.0 and Lab 1.0) Methods for measuring and analyzing motion and strain response of dynamically excited structures. Includes frequency-response testing of elementary beam, torsion bar, plate and shell structures. Experiments on the effectiveness of isolators and dynamic absorbers. Prerequisite: E Mech 361 or Mc Eng 307 or Ae Eng 307. (Co-listed with Mc Eng 362, E Mech 362)

369 Introduction to Hypersonic Flow (Lect 3.0) A study of the basic principles of hypersonic flow. Invisvid and viscous hypersonic flow. Application of numerical methods. High temperature flow. Consideration of real gas and rarefied flow. Applications in aerodynamic heating and atmospheric entry. Prerequisite: Ae Eng 271 or Mc Eng or Ae Eng 331.

371 V/STOL Aerodynamics (Lect 3.0) Basic concepts of V/STOL flight. Takeoff transition and landing performance, thrust vectoring. Propeller and helicopter aerodynamics. Unblown and blown flaps. Boundary layer control. Lift fans and ducted propellers. Wing-propeller interaction and thrust augmentation. Prerequisite: Ae Eng 271.

377 Principles of Engineering Materials (Lect 3.0) Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Ch Eng 377, Physics 377, Mt Eng 377, Cr Eng 377)

381 Mechanical and Aerospace Control Systems (Lect 3.0) Synthesis of mechanical and aerospace systems to perform specific control functions. Response and stability are studied. Singular value analysis for stability margins is introduced. Prerequisite: Mc Eng 279 or Ae Eng 361. (Co-listed with Mc Eng 381)

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six (6) credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course. Variable title. (Co-listed with Mc Eng 401)

403 Advanced Dynamics of Machinery (Lect 3.0) Current problems in machine design are tested using methods of analytical mechanics; gyroscopic phenomena; the calculus of variations; stability of systems; to include approximate techniques. Prerequisite: Ae Eng 313 or Mc Eng 313.

407 Advanced Vibrations (Lect 3.0) Advanced treatment of discrete and continuous vibratory systems. Extensive use is made of matrix methods and operator notation. Special topics include: transmission matrices, relative coordinates, time dependent boundary conditions, approximate techniques for linear systems, nonlinear systems and random excitations. Prerequisite: Mc Eng or Ae Eng 307 or E Mech 361. (Co-listed with Mc Eng 407)

408 Finite Element Approximation II-Second Course (Lect 3.0) Continuation of Finite Element Approximation I-An Introduction: element selection and interpolation estimates, Lagrange, Hermite, and Isoparametric elements; mixed, hybrid, penalty and boundary elements; eigen-value and time-dependent problems; three-dimensional and nonlinear problems. Prerequisite: E Mech 307 or Mc Eng 312 or Ae Eng 352. (Co-listed with E Mech 408, Mc Eng 408)

409 Engineering Acoustics II (Lect 3.0) Expanded treatment of the theory of sound generation and propagation. The acoustic source, dipole, and quadrupole. Noise sources due to vibration and fluid flow. Sound propagation in the atmosphere. The transmission of sound in ducts, propeller, fan, and jet noise. Prerequisite: Mc Eng or Ae Eng 309. (Co-listed with Mc Eng 409)

410 Seminar (Variable) Discussion of current topics. (Co-listed with Mc Eng 410 and E Mech 410)

413 Advanced Aerospace Mechanics (Lect 3.0) Current problems in aerospace dynamics are treated using methods of analytical mechanics; gyroscopic phenomena; the calculus of variations, stability of systems, to include approximate techniques. Prerequisite: Mc Eng or Ae Eng 313. (Co-listed with Mc Eng 413)

419 Microscopic Thermodynamics (Lect 3.0) A microscopic treatment of thermodynamic concepts using the statistical approach. The kinetic theory of an ideal gas including transport phenomena. A comprehensive introduction to Maxwell-Boltzmann and quantum statistics including the relationship between particular functions and thermodynamic properties. An introduction to the ensemble method of Gibbs for systems of dependent particles. Prerequisite: Mc Eng or Ae Eng 319. (Co-listed with Mc Eng 419)

423 Viscous Fluid Flow (Lect 3.0) Fundamentals of viscous fluids for incompressible and compressible flows governed by Navier-Stokes equations; exact, approximate, and numerical solutions for steady and unsteady laminar flows; stability, transition, and turbulence, CFD simulations of internal and external flows. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Mc Eng 423)

425 Heat Transfer by Conduction (Lect 3.0) A study of conduction of heat transfer in solids by analytical and other methods. Prerequisite: Mc Eng or Ae Eng 325. (Co-listed with Mc Eng 425)

427 Heat Transfer by Convection (Lect 3.0) An analytical study of convective heat transfer in laminar and turbulent flows; forced convection, natural convection, and mixed convection; combined heat and mass transfer; heat transfer with change of phase; instability of laminar flow; current top-

ics in convection. Prerequisite: Mc Eng or Ae Eng 325. (Co-listed with Mc Eng 427)

429 Heat Transfer by Radiation (Lect 3.0) A study of the nature of thermal radiation; implications from electromagnetic theory; radiative characteristics of surfaces; enclosures; configuration factors; radiosity; specular and diffuse reflection; transfer in absorbing, emitting and scattering media; combined radiation conduction and convection; experimental methods. Prerequisite: Mc Eng or Ae Eng 325. (Co-listed with Mc Eng 429)

431 Gas Dynamics I (Lect 3.0) A critical analysis of the phenomena governing the flow of a compressible fluid; introduction to flow in two and three dimensions; Prandtl-Meyer expansions; small perturbations in subsonic and supersonic flows; method of characteristics. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Mc Eng 431)

433 Gas Dynamics II (Lect 3.0) A continued study of compressible fluid flow phenomena; bodies of revolution and slender body theory; transonic flow; unsteady one-dimensional motion including small amplitude waves. Continous flow, and shock waves; the shock tube; shockwave boundary layer interactions. Prerequisite: Mc Eng or Ae Eng 431. (Co-listed with Mc Eng 433)

435 Turbulence in Fluid Flow (Lect 3.0) Fundamentals of statistical theory of turbulence; turbulence modeling for transport processes of heat, mass, and momentum; closure schemes for Reynolds-averaged Navier-Stokes equations in free turbulence and wall turbulence; CFD simulations of turbulent flows. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Mc Eng 435 and Ch Eng 435)

436 Rarefied Gas Dynamics (Lect 3.0) The kinetic theory of gases is applied to problems of aerodynamic interest in a low density medium. The theory of free molecular flow is developed and applied to force and moment calculations on various bodies. The Boltzmann equation is solved for free molecular flow in the satellite wake and surface flow. Prerequisite: Mc Eng or Ae Eng 331.

437 Physical Gas Dynamics I (Lect 3.0) Features of high temperature gas flows including the development of the necessary background from kinetic theory, statistical mechanics, chemical thermodynamics and chemical kinetics. Equilibrium and Nonequilibrium gas properties and gas flows are included. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Mc Eng 437)

439 Physical Gas Dynamics II (Lect 3.0) Features the study of transition regime gas dynamics including the concept of molecular velocity distribution, gas-solid interaction, the Boltzmann equation, Nonequilibrium flow and solutions to specific problems in transition flow. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Mc Eng 439)

443 Engineering Magnetohydrodynamics (Lect 3.0) Critical study of magnetohydrodynamic power generation and magnetohydrodynamic propulsion; including the study of ionization processes, gaseous conduction, fundamental equations of magnetohydrodynamics, exact solutions of magnetohydrodynamic channel flow, one dimensional approximation, boundary layer development and important parameters in magnetohydrodynamics. Prerequisite: Math 322. (Co-listed with Mc Eng 443)

451 Thermal Stresses I (Lect 3.0) A review of heat transfer principles and rigorous formulation of basic thermal stress relations with the solution of some basic practical problems. Prerequisite: Mc Eng 325. (Co-listed with Mc Eng 451)

453 Thermal Stresses II (Lect 3.0) Discussion of the basic phenomena associated with thermal stress, thermal stress fatigue, low cycle fatigue, and thermal shock. Discussion of material selection and elimination of thermal stress by design configuration. Prerequisite: Mc Eng or Ae Eng 451. (Co-listed with Mc Eng 453)

455 Structures and Materials for Extreme Environments (Lect 3.0) An advanced course in the types and selection of materials and structures with emphasis on the underlying theory of their behavior. Lubrication in the vacuum of space and ablation; recent developments in materials and fabrication techniques. Effects of vacuum radiation, corrosive agents, temperature. (Co-listed with Mc Eng 455)

479 Analysis and Synthesis of Mechanical and Aerospace Systems (Lect 3.0) A unified treatment of modern system theory for the Mechanical and Aerospace Engineering Controls Analyst, including analysis and synthesis of linear and nonlinear systems, compensation and optimization of continuous and discrete systems, and theory of adaptivity. Prerequisite: Mc Eng 381 or Ae Eng 381. (Co-listed with Mc Eng 479)

483 Aerosol Mechanics (Lect 3.0) Aerosol (hydrosol) particle motion under the influence of external forces (inertial, gravitational, electrostatic, phoretic, etc.) particle coagulation, deposition, filtration theory applied to clean rooms. Prerequisites: Mc Eng or Ae Eng 331, or Ch Eng 336.

484 Analysis of Laminated Composite Structures (Lect 3.0) An overview of isotropic beams, plates, and shells. Bending, vibration, and buckling of laminated composite beams and plates: exact and approximate solutions. Development of composite shell theory and simplified solutions. Analysis of composite structures including transverse shear deformation and thermal effects. Prerequisite: E Mech 381 or Mc Eng 382 or Ae Eng 311. (Co-listed with E Mech 484 and Mc Eng 484)

485 Mechanics of Composite Materials (Lect 3.0) Effective moduli of spherical, cylindrical and lamellar systems. Micromechanics of fiber-matrix interfaces and unidirectional composites. Application of shear leg and other approximate theories to interfaces and composites including fiber pull-out, debonding and matrix cracking. Prerequisite: E Mech 381 or Mc Eng 382 or Ae Eng 311. (Co-listed with Mc Eng 485 and E Mech 483)

487 Finite Element Approximation III - Nonlinear Problems (Lect 3.0) Formulation of nonlinear

problems, iterative methods, solution of nonlinear problems, cover topics of interest to the class. Prerequisite: E Mech 408 or Mc Eng 408 or Ae Eng 408. (Co-listed with E Mech 487 and Mc Eng 487)

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

BIOLOGICAL SCIENCES

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

310 Seminar (Variable) Presentation of a scientific paper concerned with current topics in biological sciences. Prerequisite: Senior standing.

315 Embryonic Development (Lect 3.0 and Lab 1.0) Study of the patterns of development of the vertebrate embryo, the molecular mechanisms of tissue induction, and interactions among developing tissues. Prerequisite: Bio 215.

318 Plant Physiology (Lect 3.0) The course aims to show the integration and interaction of plant activities at different levels of organization; e.g. the chloroplast, the cell, the leaf, and the whole plant. Emphasis is on understanding the mechanisms by which plants acquire energy from the environment, how this energy is used to take up water, carbon and nutrients, and how resources are transported around the plant. We examine regulation of these processes as the plant responds to changing environmental conditions.

321 Pathogenic Microbiology (Lect 3.0) A study of medically important microorganisms. Students will learn about the properties that enable organisms to cause disease as well as the disease process within the host. Special emphasis will be placed on recent advances in the molecular genetics of host pathogen interaction. Prerequisite: Bio 221 or Cv Eng 261.

322 Pathogenic Microbiology Laboratory (Lab 2.0) An investigation of techniques for the isolation and identification of pathogenic microorganisms. Prerequisite: Preceded or accompanied by Bio 321.

325 Microbiology in Bioengineering (Lect 3.0) General introduction to prokaryotic and eukaryotic microorganisms and viruses. Consideration of various parameters affecting the growth, basic techniques of culture, and industrial applications of microorganisms. Prerequisite: Bio 211.

328 Nutritional and Medicinal Properties of Plants (Lect 3.0) A survey of the biochemical and physiological functions of mineral elements, vitamins, and other organic compounds from plants necessary in human nutrition; and an overview of the medicinal derivatives of various plants, their effects and uses. Prerequisites: Bio 110 and Bio 211.

331 Molecular Genetics (Lect 3.0) A study of the properties and functions of DNA that make this macromolecule unique in the universe. Examples of replication, transcription, translation, repair, and regulation will be examined in viruses, prokaryotes, and eukaryotes. Prerequisites: Bio 231 and Bio 211.

332 Molecular Genetics Laboratory (Lab 2.0) This course provides experience in the use of a variety of DNA manipulation techniques that are common to molecular studies. These include DNA extraction, restriction mapping, Southern blotting, recombinant plasmid construction, DNA sequencing and analysis, and polymerase chain reaction. Prerequisite: Preceded or accompanied by Bio 331.

342 Exercise Physiology (Lect 3.0) Covers cardiovascular, pulmonary, and metabolic responses to aerobic and anaerobic muscular activities, work capacities, nutritional factors in performance, and role of exercise in health. Prerequisite: Bio 110.

352 Biological Effects of Radiation (Lect 3.0) Introduction to biological effects of ionizing radiation including mode of induction of mutations, effects on the developing fetus and specific tissues plus therapeutic applications of various types of radiation. Prerequisites: Bio 110 and Chem 3.

361 Cell Physiology (Lect 3.0) Consideration of the physiochemical nature of the cell, its relationship with environment, and its metabolic pathways. Prerequisite: Bio 211.

365 Comparative Animal Physiology (Lect 3.0) A comparative study of functional relationships, physiological adaptations, and survival strategies which are observed among various groups of animals as they respond to natural environmental conditions. Emphasis is placed on relating biochemical function and phylogenetic relationships. Prerequisites: Bio 215, Chem 223, and Bio 211 or Chem 361.

370 Toxicology (Lect 3.0) A study of natural and man-made toxicants, various possible routes of exposure, absorption, distribution, biotransformation, specific target sites, and mechanisms involved in elicitation of toxic effects, as well as

detoxification and excretion. Prerequisites: Bio 211 plus either Bio 215 or 242.

375 Advanced Biology Lab Techniques I (Variable) Advanced level laboratory designed to acquaint students of cellular and molecular biology with techniques employed in current research. Students select one to three miniprojects, each designed to involve 40 to 45 hours of library and laboratory work. Prerequisite: Junior or senior standing in Biological Sciences or related field plus consent of instructor.

376 Advanced Biology Lab Techniques II (Variable) Continued laboratory study of current bioresearch techniques. Further work with miniprojects. Prerequisite: Junior or senior standing in Biological Sciences or related field plus consent of instructor.

381 Immunology (Lect 3.0) A study of the principles of immunology, including biological and biochemical aspects of the immune response, immunochemistry, serology, immunoglobulin and T-cell mediated allergies, tumor and transplantation immunology, autoimmune diseases, and the role of immunity in host defense. Prerequisites: Chem 223 or Chem 363 and Bio 211.

391 General Virology (Lect 3.0) An overview of the field of virology, including plant, animal, and bacterial viruses. Discussions will include morphology, classification, virus-host interactions, genetics, clinical and industrial aspects of viruses, and viruses as model systems for basic biological studies. Prerequisites: Bio 110, 211, 221, Chem 1, 3, 221.

402 Problems in Applied and Environmental Biology (Lect 2.0) Overview of major areas of research in applied biology and environmental science with a focus on interdisciplinary approaches used on UMR campus in ongoing research. Prerequisite: Acceptance to Graduate Program.

410 Graduate Seminar (Variable) Presentation and discussion of current topics in Applied and Environmental Biology.

418 Plant Stress Physiology (Lect 3.0) Course covers plant responses to environmental stress. Physiological anatomical, biochemical and molecular responses to both biotic and abiotic stresses. Prerequisites: Bio 211, Bio 218 and 219 and Chem 361.

421 Advanced Microbial Metabolism (Lect 3.0) A survey of the diverse metabolic properties of microorganisms. Course material will emphasize major metabolic pathways and how they relate to microbial diversity and microbial ecology. Prerequisite: Bio 221 or an equivalent course.

422 Biomolecules (Lect 3.0) Demonstration of the principles of modern biochemistry as they relate to the structure and function of the major macromolecules of the cell. An emphasis will be placed on reading and interpreting scientific literature and scientific writing. Prerequisites: Bio 211 and/or Chem 361 or an equivalent course.

442 Mammalian Physiology (Lect 3.0) Advanced study of the physiology of mammalian organ systems with a focus on membrane biophysics, endocrine control of metabolism, organ interactions, and homeostatic mechanisms. Prerequisites: Bio 211 plus either Bio 215 or Bio 242.

451 Environmental Microbiology (Lect 3.0) Topics to be explored in this course will include but are not limited to microbial growth and metabolic kinetics, life in extreme conditions, biogeochemical cycling, bioremediation of contaminants, waterborne pathogens and environmental biotechnology. Prerequisite: Must be a graduate student.

452 Space Biology (Lect 3.0) The origins of life on early earth and the possibility of life on extraterrestrial bodies will be explored. In addition, the instruments and methods to carry out space travel, necessary for studying the possibility of extraterrestrial life. Prerequisite: Graduate standing.

455 Bioremediation (Lect 3.0) During this course, the use of microorganisms and other living organisms for the remediation of contaminated environments will be explored along with the techniques necessary for monitoring their activities. Prerequisite: Graduate standing.

461 Advanced Cell Biology (Lect 3.0) Advanced study of the biology of eukaryotic cells, including biomembranes and membrane transport, subcellular organelles, cellular energetics, protein sorting, cytoskeletal elements, cell to cell signalling, regulation of the cell cycle, and tissue organization. Prerequisite: Bio 211 or equivalent.

475 Techniques in Applied and Environmental Biology (Lect 3.0) Students will have the opportunity for hands on experience with the various techniques used in the modern biology laboratory. Techniques will include gene cloning, DNA sequencing, protein purification, growth and development of various model organisms, data acquisition. Prerequisite: Graduate standing.

490 Graduate Research (Variable) Investigation of an advanced nature leading to the preparation of a thesis or dissertation.

CERAMIC ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

306 Thermomechanical Properties and Their Use in Design (Lect 3.0) This course will treat the theory and testing practice related to design for a range of thermal and mechanical properties of ceramic materials. Prerequisite: Bas En 110.

308 Electrical Ceramics (Lect 2.0 and Lab 1.0) The application and design of ceramics for the electrical industry is discussed. Particular emphasis is placed on how ceramic materials are altered to meet the needs of a specific application. The lab-

oratory acquaints the student with measurements which are used for electrical property evaluation. Prerequisite: Cr Eng 284.

315 Organic Additives in Ceramic Processing (Lect 2.0) Basic chemistry, structure and properties or organic additives used in the ceramics industry; solvents, binders, plasticizers, dispersants. Use of organic additives in ceramic processing. Prerequisites: Cr Eng 203 and 231.

331 Ceramic Processing (Lect 3.0) Powder, colloidal and sol-gel processing, forming methods, drying, sintering and grain growth. Relation of processing steps to densification and microstructure development. Prerequisite: Senior standing.

333 Microelectronic Ceramic Processing (Lect 3.0) Materials, processing and design of microelectronic ceramics are covered. Introduction to devices, triaxial ceramics, high aluminas, tape fabrication, metallizations, thick film processing and glass-to-metal seals. Prerequisites: Cr Eng 203 & 242.

362 Thermomechanical/Electrical/Optical Properties Lab (Lab 1.0) Laboratory consisting of three separate modules of experiments for the characterization of the thermomechanical, electrical and optical properties of ceramics. The student will choose one of the three modules. Prerequisite: Bas En 110 or Cr Eng 284.

364 Refractories (Lect 3.0) The manufacture, properties, uses, performance, and testing of basic, neutral and acid refractories.

369 Glass Science and Engineering (Lect 3.0) The development, manufacturing methods, applications, and properties of flat, fiber, container, chemical, and special purpose glasses. Composition/property relationships for glasses and nucleation-crystallization processes for glass-ceramics are also covered. Prerequisite: Cr Eng 102.

371 Dielectric and Electrical Properties of Oxides (Lect 3.0) The processes occurring in inorganic materials under the influence of an electric field are considered from basic principles. Emphasis is placed on application to real systems. Prerequisite: Cr Eng 284.

377 Principles of Engineering Materials (Lect 3.0) Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Ae Eng 377, Ch Eng 377, Physics 377, Mt Eng 377)

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six (6) credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

391 X-ray Diffraction and Fluorescence (Lect 3.0) Symmetry and space groups; x-ray diffraction; reciprocal lattice; calculated diffracted beam intensity; indexing methods; precise lattice parameters.

392 X-ray Diffraction and Fluorescence Laboratory (Lab 1.0) Qualitative and quantitative analysis by diffraction and fluorescence; high temperature studies of expansion and kinetics of phase formation or transformation. Prerequisite: Preceded or accompanied by Cr Eng 391.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

405 Interfacial Phenomena (Lect 3.0) The nature and constitution of inorganic interfaces, surface processes and consequences, epitaxy, thermal grooving, UHV techniques, field emission-ionization and evaporation, surface models, adsorption and nucleation.

407 Behavior of Materials, VI-Mechanical (Lect 3.0) Recent theories for the fracture of brittle materials, crystalline and noncrystalline, in relation to defects, both microscopic and submicroscopic, and techniques for determining strength of brittle materials.

410 Seminar (Variable) Discussion of current topics.

414 Advanced Crystal Chemistry (Lect 3.0) Detailed treatment of crystal structure notation, space group symmetry, and bonding in complex structures. Symmetry changes and bonding relationships associated with thermal variations. Prerequisite: Chem 243.

418 Optical Properties of Materials (Lect 3.0) The objective of this course is to give the student a fundamental understanding of the structure-optical property relationships exhibited by isotropic and anisotropic materials. Topics will include the wave/particle nature of light, how light interacts with materials, color, and applications such as lasers, fiber optic communication systems, electro-optics, and integrated optics. Prerequisites: Physics 24 or 25 and Math 22.

423 Sintering and Microstructure Development (Lect 3.0) Theory and practice of densification, microstructure evolution, effect of processing and material factors, grain boundary migration, grain growth. Prerequisite: Graduate standing.

444 Instructional Education for Graduate Students (Lect 1.0) In this course graduate students will participate in scholarly tasks to give them useful experience in undergraduate instruction and research. Skills will be developed to effectively educate students, and interactive discussions will focus on the development of new instructional methods. Prerequisite: Graduate student in Ceramic Engr.

445 Instructional Education for Graduate Students (Lect 1.0) Continuation of Cer 444. Prerequisite: Graduate Students in Ceramic Engr.

458 Electroceramic Composite (Lect 3.0) The objective of this course is to give the student an understanding of the structure-property relationships exhibited by electroceramic composites. The composites of interest cover a wide range of electrical phenomena including composite dielectrics, piezoelectrics, conductors, magnets, and optics. Prerequisite: Cr Eng 284.

460 Crystal Anisotropy (Lect 3.0) The objective of this course is to give the student an understanding of crystal structure-physical property relationships. The relationship between symmetry and tensor representation will be examined, and then related to the mechanical, electrical and optical properties exhibited by the materials. Prerequisite: Cr Eng 102.

477 Atomic Structure in Solid State Materials (Lect 4.0) The principles of chemical bonding in solids are discussed in terms of electronic structure and chemical bonding. The crystallography of perfect crystals is described along with reciprocal lattices and tensor properties. Finally, the characterization of crystalline materials is discussed. Prerequisite: Graduate standing.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

491 Internship (Variable) Students working toward a doctor of engineering degree will select with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

CHEMICAL ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

331 Principles of Chemical Engineering (Lect 3.0) Study of newer unit operations, fluidization, chromatographic absorption, new developments in operations previously studied. Comparison of operations which might be selected for the same end result in an industrial process. Prerequisites: Ch Eng 235, 237.

333 Separation Processes for Product Purification (Lect 3.0) Fundamentals of separation operations such as extraction and distillation; rates of diffusion in equilibrium stages and continuous contactors; efficiencies; multistage contactors; performance of equipment; phase equilibrium data; multicomponent separation. Prerequisites: Ch Eng 235, 237.

335 Momentum, Heat and Mass Transfer (Lect 3.0) The similarities of flow of momentum, heat and mass transfer and the applications of these underlying principles are stressed. Course is primarily for seniors and beginning graduate students. Prerequisites: Ch Eng 235, 237, Math 204.

341 Physical Property Estimation (Lect 3.0) Techniques for estimating and correlating thermodynamic and transport properties of gases and liquids will be studied. Prerequisites: Ch Eng 143, 237.

342 Experimental Methods in Chemical Engineering (Lab 3.0) Several students work together as a group for the entire semester to calibrate and operate sophisticated equipment with the objective of measuring, correlating, and documenting new data. A final report in the form of a paper is required. Prerequisite: Ch Eng junior or senior status.

343 Chemical Engineering Kinetics (Lect 3.0) A study of homogeneous and heterogeneous catalyzed and noncatalyzed reaction kinetics for flow and batch chemical reactors. Application to reactor design is stressed. Prerequisite: Ch Eng 243.

344 Interdisciplinary Problems in Manufacturing Automation (Lect 2.0 and Lab 1.0) The course will cover material necessary to design a product and the fixtures required to manufacture the product. Participants will gain experience with CAD/CAM software while carrying out an actual manufacturing design project. Prerequisites: Senior standing and permission of instructor. (Co-listed with Mc Eng 344, Eng Mg 344)

345 Chemical Engineering in Biochemical Technology (Lect 3.0) An introduction to the use of chemical engineering principles in the areas of fermentation, enzyme catalysis, and biological transport phenomena, with emphasis on food, chemicals, medicine and pharmaceuticals, fuels, and waste treatment. Prerequisites: Ch Eng 235, 237.

351 Principles of Environmental Monitoring (Lect 3.0) This course provides an overview of environmental monitoring methodologies. Discussion covers thermodynamic and kinetic processes that affect chemical transport and fate in the environment. Federal environmental regulations and re-

mediation technologies are also covered with specific examples. Prerequisites: Chem 51, 221, 223, and Physics 23, 24.

353 Unit Processes - Organic Chemical Industry (Lect 3.0) A detailed study of the fundamental unit processes of organic chemistry. Prerequisites: Ch Eng 235, 237, Chem 221. (Co-isted with Chem 325)

357 Industrial Pollution Control (Lect 3.0) The study of water, air, and thermal pollution control methods and the application of these methods to the solution of pollution problems in the chemical industry. Prerequisites: Ch Eng 235, 237.

361 Environmental Chemodynamics (Lect 3.0) The objective of the course is to introduce students to interphase transport of chemicals and energy in the environment. The process oriented aspects of chemical engineering - fundamental chemistry, thermodynamics, fluid mechanics, mass transport, heat transport, equilibrium and separations - are extended to the situations found in the environment where the same principles apply. This course is designed to complement Ch Eng 351, Environmental Monitoring. Prerequisites: Ch Eng 141 or equivalent, Ch Eng 231 or equivalent, Ch Eng 233 or equivalent, Chem 1, 2, and 3 or Chem 5.

362 Pollution Prevention via Process Engineering (Lect 3.0) In the context of environmental process design each processing system is considered as an interconnection of elementary units. Systematic process integration methods are then employed that capitalize on synergistic process interactions in order to arrive at environmentally benign process designs. The proposed course on Pollution Prevention via Process Engineering introduces paradigms such as: linear, nonlinear and integer optimization, mass/heat exchange networks, reactor and reaction networks that are instrumental in the analysis, synthesis and design of environmental systems. Pollution prevention case studies that employ the aforementioned concepts will be incorporated in the presentation.

365 Process Dynamics (Lect 3.0) A study of the dynamic properties of engineering operations and the interrelationships which result when these operations are combined into processes. Formulation of equations to describe open-loop and closed-loop systems. Prerequisites: Ch Eng 235, 237, 261.

366 Chemical Process Simulation (Lab 1.0) Simulation of Engineering and chemical processes on digital and/or analog devices with application to pilot scale processes. Prerequisite: Ch Eng 262.

367 Plantwide Process Control (Lect 3.0) Synthesis of control schemes for continuous and batch chemical plants from concept to implementation. Multiloop control, RGA, SVD, constraint control, multivariable model predictive control, control sequence descriptions. Design project involving a moderately complicated multivariable control problem. Prerequisites: Ch Eng 261 or El Eng 231. (Co-listed with El Eng 332)

368 Chemical Process Flowsheeting (Lect 3.0) The development, implementation, and evaluation of methods for determining the mathematical model of a chemical process, ordering the equations in the mathematical model, and solving the model. Prerequisites: Cmp Sc 73, Math 204.

375 Structure and Properties of Polymers (Lect 3.0) A study of the parameters affecting structure and properties of polymers. Syntheses, mechanisms, and kinetic factors are emphasized from the standpoint of structural properties. Prerequisites: Chem 223, Chem 243.

377 Principles of Engineering Materials (Lect 3.0) Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Ae Eng 377, Physics 377, Mt Eng 377, Cr Eng 377)

381 Corrosion and its Prevention (Lect 3.0) A study of the theories of corrosion and its application to corrosion and its prevention. Prerequisite: Chem 243.

387 Interfacial Phenomena in Chemical Engineering (Lect 3.0) The course deals with the effects of surfaces on transport phenomena and on the role of surface active agents. Topics include fundamentals of thermodynamics, momentum, heat and mass transfer at interfaces and of surfactants. Some applications are included. Prerequisites: Ch Eng 237, Math 204.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

410 Seminar (Variable) Discussions of current topics.

433 Advanced Chemical Engineering (Lect 3.0) Course is concerned with all aspects of transport phenomena. Complete expressions for heat, mass and momentum transfer in all three coordinate systems are applied under both laminar and turbulent conditions.

435 Turbulence in Fluid Flow (Lect 3.0) Fundamentals of statistical theory of turbulence; turbulence modeling for transport processes of heat, mass, and momentum; closure schemes for Reynolds-averaged Navier-Stokes equations in free turbulence and wall turbulence; CFD simulations of turbulent flows. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Mc Eng 435 and Ae Eng 435)

436 Theory and Practice of Liquid Mixing (Lect 3.0) Introduction to turbulence theory; diffusion in pipes; packed beds and fluidized beds; theories of turbulent diffusion; power correlations and scale up methods for mixers, batch mixing; response techniques to study mixing.

439 Chemical Engineering Fluid Dynamics (Lect 3.0) Fundamentals of Newtonian flow, non-Newtonian flow, flow through packed beds, two phase flow, flow around submerged objects and other related topics are discussed.

441 Advanced Chemical Engineering Thermodynamics (Lect 3.0) Extension of thermodynamic principles as applied to nonideal systems. Use of existing thermodynamic data and correlations with emphasis on applications of chemical engineering problems in energy, mass and momentum transfer.

443 Chemical Engineering Kinetics-Advanced Topics (Lect 3.0) A study of homogeneous and heterogeneous reaction kinetics and catalysis with special emphasis on effects of mixing in design and scale-up of chemical reactors.

453 Advanced Process Design, Simulation and Control Studies (Lect 3.0) The use of advanced methods of economic, engineering, optimizing, and control techniques in planning, designing, and operating chemical process industries. Topics may be adjusted to include those of special interest or need in the above fields.

461 Applied Mathematics in Chemical Engineering (Lect 3.0) Application of ordinary and partial differential equations in the solution of chemical engineering problems, particularly in the unit operations. Infinite series, numerical analysis, graphical methods, theory of errors, and precision of measurements are included.

462 Applications of Optimization Theory (Lect 3.0) An introduction to modern optimization techniques having applications in engineering economics, data analysis, process design and dynamics; methods such as Fibonacci, Partan, steep ascent, geometric, mathematical and dynamic programming.

475 Plasma Polymerization (Lect 3.0) Fundamental aspects of polymer formation in plasma (weakly ionized gas), and properties of polymers formed by such a process will be studied. Prerequisite: Ch Eng 375.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

491 Internship (Variable) Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

CHEMISTRY

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Prerequisite: Preceded or accompanied by Chem 4 or an equivalent training program approved by UMR. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

305 Advanced Chemical Preparations and Techniques (Lect 1.0 and Lab 2.0) A course designed to develop facility in the use of equipment and techniques commonly used in advanced work in experimental chemistry. Prerequisite: Preceded or accompanied by Chem 4 or an equivalent training program approved by UMR.

310 Undergraduate Seminar (Lect 1.0) Written and oral presentations of current topics in chemistry. This course may serve as part of the capstone requirement for chemistry majors.

321 Intermediate Organic Chemistry I (Lect 3.0) An advanced course designed to give the student a mastery of the fundamentals of organic chemical reactions and theory. Prerequisites: Chem 223 and 243.

323 Intermediate Organic Chemistry II (Lect 3.0) A systematic study of organic reactions, their mechanisms and synthetic applications. Prerequisites: Chem 223 and 243.

325 Unit Processes - Organic Chemical Industry (Lect 3.0) A detailed study of the fundamental unit processes of organic chemistry. Prerequisite: Chem 221. (Co-listed with Ch Eng 353)

328 Organic Synthesis and Spectroscopic Analysis (Lect 1.0 and Lab 2.0) Advanced methods for the multistep synthesis and characteriza tion of organic compounds. Modern instrumental methods of identification of organic compounds. Prerequisites: Chem 4, Chem 223, Chem 228.

331 Selected Topics in Inorganic Chemistry (Lect 3.0) A study of inorganic chemistry with emphasis on physical methods. General subjects covered include: molecular structure, bonding, complex-

es, spectroscopy, and reaction rates. Prerequisite: Preceded or accompanied by Chem 243.

338 Advanced General Chemistry for Secondary Teachers (Lect 3.0 and Lab 1.0) A study of the general principles of chemistry with emphasis on the fundamental laws and their application in practical applications. The laboratory experiments are designed to support lectures and to be used as teaching demonstrations in high schools. Prerequisite: One year of college chemistry.

343 Introduction to Quantum Chemistry (Lect 3.0) A study of molecular structures and spectroscopy, statistical thermodynamics, kinetic theory, chemical kinetics, crystals, and liquids. Prerequisites: Math 22 & Physics 25 or equiva-lents.

344 Advanced Physical Chemistry (Lect 3.0) Advanced undergraduate treatments of statistical mechanics, kinetics, group theory, and spectroscopy. Prerequisite: Chem 343.

346 Chemical Thermodynamics (Lect 3.0) A study of the laws of thermodynamics with application to chemical systems. Emphasis is placed on partial molal functions. Prerequisite: Chem 243.

349 The Physical Chemistry of Colloidal Dispersions (Lect 3.0) The stability of colloidal systems is treated using the kinetic approach with interparticle potentials. The results are extended to practical systems of microemulsions, emulsions and foams. Prerequisite: Chem 343.

351 Advanced Analytical Chemistry (Lect 3.0) Theoretical and practical aspects of modern analytical chemistry. Prerequisite: Chem 251.

355 Instrumental Methods of Chemical Analysis (Lect 3.0 and Lab 1.0) Principles and analytical applications of molecular spectroscopy, chromatographic separations, mass spectrometry, and radiochemistry. A brief overview of instrument electronics, signal generation and processing, and automated analysis is also provided. Prerequisites: Chem 4, Chem 52, Chem 223, Chem 243.

361 General Biochemistry (Lect 3.0) A resume of the important aspects of quantitative and physical chemistry in biochemical processes. General subjects covered include: proteins, nucleic acids, enzymes, carbohydrates and lipids. Prerequisites: Chem 223 and Bio 211.

362 General Biochemistry Laboratory (Lab 2.0) Experiments are integrated with the lectures and cover the chemical and physical properties of proteins, enzymes, nucleic acids, carbohydrates and lipids. Prerequisites: Preceded or accompanied by Chem 361 and Chem 4 or an equivalent training program approved by UMR.

363 Intermediary Metabolism (Lect 3.0) A continuation of Chem 361. Catabolism and anabolism of carbohydrates, lipids, proteins, and nucleic acids. Photosynthesis, oxidative phosphorylation and membranes. Prerequisite: Chem 361.

367 Industrial Biochemistry (Lect 3.0) A study of the problems involved in the utilization of biological systems for the production of bulk chemicals, the preparation of biologicals and the treatment of waste from plants producing biologicals and foodstuffs. Prerequisite: Junior standing.

371 Nuclear and Radiochemistry (Lect 3.0 and Lab 1.0) A study of the fundamentals of nuclear and radiochemistry including properties of radiations; effect of radiation on materials, production, measurement and use of radioactive tracers; and the chemistry of reactor materials. Laboratory training includes radiochemistry technology. Prerequisites: Physics 107 or 207 and preceded or accompanied by Chem 4 or an equivalent training program approved by UMR.

373 Atmospheric Chemistry (Lect 3.0) A chemical study of the troposphere including composition; nucleation, growth stability, distribution, diffusion, and fallout of aerosols; and meteorological aspect. Prerequisite: Chem 243.

375 Principles of Environmental Monitoring (Lect 3.0) This course provides an overview of environmental monitoring methodologies. Discussion covers thermodynamic and kinetic processes that affect chemical transport and fate in the environment. Federal environmental regulations and remediation technologies are also covered with specific examples. Prerequisites: Chem 221, Physics 25.

381 Chemistry and Inherent Properties of Polymers (Lect 3.0) A basic study of the organic chemistry of natural and synthetic high polymers, their inherent properties and their uses in plastic, fiber, rubber, resin, food, paper and soap industries. Prerequisite: Chem 223.

384 Polymer Science Laboratory (Lect 1.0 and Lab 2.0) Lectures and laboratory experiments dealing with polymerization reactions, solution properties and bulk or solid properties will be presented. Each student will prepare polymers and carry out all characterization experiments on actual samples. Prerequisite: Chem 381 or Ch Eng 375, preceded or accompanied by Chem 4 or an equivalent training program approved by UMR.

385 Fundamentals of Protective Coating I Lect 3.0 Study of the basic principles of protective coatings with particular reference to the paint and varnish industry. Classifications, manufacture, properties and uses of protective coatings. Prerequisite: Chem 223.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Does not lead to the preparation of a thesis. Not more than six (6) credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor. Preparation of a written, detailed report is required of the student. Prerequisite: Must meet departmental requirements for instruction in laboratory safety. Consent of instructor required.

400 Special Problems (Variable) Problems or reading on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

410 Seminar (Variable) Discussion of current topics.

421 Advanced Organic Chemistry (Lect 3.0) An advanced study of organic chemistry including name reactions and current theory. Prerequisite: Chem 223.

423 Advanced Topics in Organic Chemistry (Lect 3.0) A group of courses offered periodically, discussing recent and current material taken primarily from chemical journals. One of the following topics is offered each semester: molecular rearrangements; advances in total synthesis; the chemistry of isoprenoid compounds; the chemistry of alkaloids and heterocycles; the chemistry of organo-nitrogen, phosphorus, silicon and metal compounds; bio-organic mechanisms. Prerequisite: Chem 227.

425 Physical Organic Chemistry (Lect 3.0) An advanced course in theoretical organic chemistry treating molecular orbital theory, free energy relationships, transition state theory, and other fundamental topics. Prerequisite: Chem 321.

431 Inorganic Reaction Mechanisms (Lect 3.0) A study of the reaction mechanisms of inorganic compounds involving both metallic and nonmetallic elements. The topics covered include, substitution, exchange, oxidation-reduction and electron transfer reactions in inorganic systems. Prerequisite: Chem 237 or Chem 331.

435 Principles of Inorganic Chemistry (Lect 3.0) A systematic study of modern and theoretical inorganic chemistry, based on the periodic classification. Prerequisites: Chem 237 and 331.

437 Principles of Inorganic Chemistry (Lect 3.0) A continuation of Chem 435 with special emphasis on the transitional elements. Prerequisites: Chem 237 and Chem 331.

438 Inorganic Materials Chemistry (Lect 3.0) Chemical processing of solid materials. Introduction to point groups, space groups, and x-ray diffraction. Bonding in solids - from molecular orbital theory to band theory. Nonstoichiometric materials and Kroger-Vink notation. Optical and electrical properties of semiconductors. Epitaxial growth. Quantum effects in nanophase materials. Prerequisite: Chem 331 or permission of instructor.

440 The Physical Chemistry of Colloidal Dispersions (Lect 3.0) A study of the properties of colloidal systems. Prerequisite: Chem 243.

441 Physical Chemistry of Surfaces (Lect 3.0) Absorption at liquid interfaces and properties of surface films. Physical and chemical absorption on solid surfaces. Catalysis.

442 Neutron Diffraction (Lect 3.0) A study of neutron diffraction techniques as applied to nuclear and magnetic structures of alloys, compounds, single crystal and polycrystalline materials. Prerequisites: Physics 25 and 26.

443 Advanced Chemical Thermodynamics (Lect 3.0) Partial molar enthalpy and free energy. The third law of thermodynamics measurement of absolute entropy and correlation of thermodynamic properties. Microscopic and macroscopic theory of non-equilibrium thermodynamics. Prerequisite: Chem 243.

444 Spectroscopy (Lect 3.0) Introduction to the interaction of electromagnetic radiation with matter. Emphasis on the ultraviolet, visible, and radio portions of the spectrum. Prerequisite: Chem 343 or equivalent.

445 Quantum Chemistry I (Lect 3.0) A rigorous introduction to the fundamental concepts and principles of quantum chemistry. Application to translational, vibrational, and rotational motion; one-electron systems. Prerequisite: Chem 343 or equivalent.

446 Quantum Chemistry II (Lect 3.0) Atomic and molecular quantum mechanics. Emphasis on self-consistent field, variational, and perturbation theories. Introduction to approximate methods. Prerequisite: Chem 343 or equivalent.

447 Statistical Thermodynamics (Lect 3.0) Derivation of the partition function and its application to chemical systems. Prerequisite: Chem 243.

449 Chemical Kinetics (Lect 3.0) An introduction to the deduction of mechanisms of homogeneous chemical reactions from rate-data. Selected topics, such as photochemistry, free-radical mechanisms, catalysis, and explosion reactions. Prerequisite: Chem 243.

451 Advanced Quantitative Analysis (Lect 3.0) A study of the quantitative analysis of the chemical elements based on their periodic arrangement and group separations. Emphasis is placed on the analysis of the less common elements. Prerequisite: Chem 251.

453 Separations (Lect 3.0) An in-depth study of all types of analytical and preparativescale separations. A special emphasis will be placed on chromatography and chromatographic theory. Prerequisite: Chem 351.

455 Chemical Spectroscopy (Lect 3.0) A study of the electronic, vibrational, rotational and nuclear magnetic resonance spectra of atoms and molecules. A basic understanding of the underlying theoretical principles and the interpretations of results is stressed. Prerequisite: Chem 351, Chem 343 or equivalent.

457 Electrochemistry (Lect 3.0) Introduction to the fundamentals, methods and applications of electrochemistry. Fundamentals cover the thermodynamics/kinetics of electrode reactions, and the modes of mass transport in the electrolyte. Methods cover potentiometric, amperometric, and a.c. techniques. Applications focus on analysis and study of materials. Prerequisite: Chem 243.

458 Principles and Applications of Mass Spectrometry (Lect 3.0) The course covers fundamental physical principles of mass spectrometry, instrumentation, interpretation of spectra, and applications in environmental, polymer, biomed-

ical, and forensic fields. Prerequisite: Chem 251 or equivalent.

464 Free Radicals in Biochemistry (Lect 3.0) The study of the basic principles of free radical chemistry and biochemistry. Prerequisites: Chem 221, Chem 223 and Bio Sci 211.

465 Enzymology (Lect 2.0 and Lab 1.0) The study of the chemical and physical properties, mechanisms of action, and commercial uses of enzymes. Laboratory experiments are designed to illustrate the catalytic properties of enzymes. Prerequisites: Chem 361 and 362.

467 Intermediary Metabolism and Biosynthesis (Lect 3.0) The course covers the biosynthesis and metabolism of nucleic acids, carbohydrates, lipids and proteins. Prerequisite: Chem 363.

468 Advanced Biochemical Techniques (Lab 2.0) Offers training in techniques and manipulation of equipment, sterile procedures, isolation and identification of biochemical material. Prerequisite: Chem 362.

471 Advanced Nuclear Chemistry (Lect 3.0) A study of the production and decay of nuclei, radioactive dating techniques, and the abundance and origin of the chemical elements. Prerequisites: Chem 371, Physics 107 or 207.

472 Radiation Chemistry (Lect 3.0) A study of the chemical and physical effects of high energy radiation in nonmetallic fluids, gases, liquids, and solids. Prerequisite: Chem 371, Physics 107 or 207.

484 Polymer Physical Chemistry and Analysis (Lect 3.0) A study of the physical properties of macromolecular systems including polymer solutions, gels, bulk polymers and rubbers. The chemical characterization of polymers based on their thermal, spectroscopic, microstructure and molecular weight is also discussed. Prerequisites: Chem 223 and Chem 243.

486 Inorganic Polymers (Lect 3.0) A basic study of inorganic natural and synthetic polymers, their formation and reactivity, their inherent properties, methods of characterization and applications. Prerequisite: Chem 237 or equivalent.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Must meet departmental requirements for instruction in laboratory safety. Consent of instructor required.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

497 Theory of Chemical Research (Lect 3.0) The design of research experiments in various subfields of chemistry and the evaluation of research results with the aid of examples taken from the current literature.

CIVIL ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course. Variable title.

302 Geomatics (Lect 3.0) Horizontal and vertical geodetic datums and networks. Theory, calculations and applications of State Plane Coordinate Systems. Introduction to Geographic and Land Information Systems: hardware and software issues; data quality and accuracy; resource, environmental, cadastral and governmental applications; databases; GIS/LIS trends. Introduction to Global Positioning Systems (GPS): Project planning, data collection, data processing and network adjustment applications, Kinematic and RealTime GPS applications, hardware and software options and costs. Prerequisite: Cv Eng 1 with grade of "C" or better.

304 Legal Aspects of Boundary Surveying (Lect 3.0) The U.S. Public Land Survey System (USPLSS): original GLO survey instructions and procedures. Resurveys on the USPLSS law, standards, procedures with emphasis on Missouri. Rights in real property; statute, case and administrative law applied to boundaries. Simultaneous and sequence conveyances. Unwritten rights in real property. Riparian boundaries. Writing and interpreting boundary descriptions. Land surveyor duties and responsibilities. Prerequisite: Cv Eng 1 with grade of "C" or better.

306 Surveying Systems (Lect 3.0) Celestial observations for azimuths. Introduction to State Plane Coordinate systems. Theory and calculations. Route surveying and geometrics, horizontal, spiral and vertical curves. Surveying aspects of residential and commercial subdivision design: lot layout, rights of way, easements, setbacks, platting, planning and zoning constraints, application of surveying software. Instrumentation: total stations, electronic levels, instrument calibrations. Prerequisite: Cv Eng 1 with grade of "C" or better.

310 Seminar (Lect 1.0) Discussion of current topics. Prerequisite: Senior standing.

311 Geometric Design of Highways (Lect 2.0 and Lab 1.0) Development and applications of concepts of geometric design for rural and urban highways. Design controls and criteria; elements

of design, including sight distance, horizontal and vertical alignment; cross-section elements; highway types; intersection design elements; types of interchanges and interchange design elements; grade separations and clearance; development of visual elements. Prerequisites: Cv Eng 211 with grade of "C" or better.

312 Bituminous Materials (Lect 2.0 and Lab 1.0) Properties, types, and grades of bituminous materials are presented. Emphasis is placed on usage, distress, surface treatment design, and asphalt concrete mix properties, behavior, design manufacture, and construction. Prerequisite: Preceded or accompanied by Cv Eng 216.

313 Composition and Properties of Concrete (Lect 3.0) Properties of plastic and hardened concrete and the influence of cements, aggregates, water and admixtures upon these properties. The microstructure of cement gel and other factors are related to the behavior of hardened concrete under various types of loading and environments, drying shrinkage, creep and relaxation, fatigue, fracture, and durability. Introduction to statistical quality control of concrete production. Prerequisite: Preceded or accompanied by Cv Eng 216.

314 Geosynthetics in Engineering (Lect 3.0) Geotechnical principles are applied to design of geosynthetic systems for foundation support, earth retention, drainage, and disposal of hazardous conventional wastes. Geosynthetic testing and identification. Emphasis is on design of geosynthetic earth reinforcement, roadway stabilization, filters, and waste containment systems. Prerequisites: Cv Eng 215 with grade of "C" or better.

315 Intermediate Soil Mechanics (Lect 3.0) General principles of soil mechanics and their applications, including mineralogy, soil structure, flow through porous media, shear strength, slope stability and consolidation. Prerequisites: Cv Eng 215 with grade of "C" or better.

316 Soil Dynamics I (Lect 3.0) Damage to structures during earthquakes, magnitude and intensity scales, theory of vibrations, single and two degrees of freedom, earthquake spectrum, dynamic soil properties, simple solutions of liquefaction, retaining structures, piles and embankments. Prerequisites: Cv Eng 215 with a grade of "C" or better.

317 Pavement Design (Lect 3.0) Structural design of rigid and flexible pavements including loading characteristics, properties of pavement components, stress distribution and the effects of climatic variables on design criteria. Prerequisites: Preceded or accompanied by Cv Eng 216 and Cv Eng 229.

318 Smart Materials and Sensors (Lect 2.0 and Lab 1.0) Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multidisciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior Standing and Math 204. (Co-listed with Ae Eng, E Mech, Mc Eng and El Eng 329)

319 Applied Mechanics in Structural Engineering (Lect 3.0) A study of the basic relationships involved in the mechanics of structures. Topics include basic elasticity, failure criteria, fundamental theories of bending and buckling of plates and cylindrical shells for practical application in analysis and design of bridge, building floors, and shell roofs. Prerequisite: Cv Eng 218.

322 Analysis and Design of Wood Structures (Lect 3.0) A critical review of theory and practice in design of modern wood structures. Effect of plant origin and physical structure of wood on its mechanical strength; fasteners and their significance in design; development of design criteria and their application to plane and three dimensional structures. Prerequisites: Cv Eng 218 with grade of "C" or better.

323 Classical and Matrix Methods of Structural Analysis (Lect 3.0) Classical displacement and force methods applied to structures of advanced design. Displacement matrix methods and computer techniques applied to continuous beams, frames and trusses, plane grid and three-dimensional frames. Prerequisites: Cv Eng 218 with grade of "C" or better.

324 Numerical Methods of Structural Analysis (Lect 3.0) The application of numerical integration techniques for determining shears, moments, slopes and deflections of beams and frames. Numerical techniques for structural element stability. Application of finite difference methods on one and two dimensional structural systems. Prerequisites: Cv Eng 218 with grade of "C" or better.

326 Advanced Steel Structures Design (Lect 2.0 and Lab 1.0) The design of structural steel systems into a final integrated structure. Plate girders, composite systems, stability, connections, rigid frames, single and multistory buildings, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisites: Cv Eng 221 with a grade of "C" or better.

327 Advanced Concrete Structures Design (Lect 2.0 and Lab 1.0) The design of structural concrete systems into a final integrated structure. Two-way slabs, long columns, connections, and discontinuity regions, deflections and cracking of beams and slabs, ACI design criteria, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisites: Cv Eng 223 with a grade of "C" or better.

328 Prestressed Concrete Design (Lect 3.0) Behavior of steel and concrete under sustained load. Analysis and design of pre-tensioned and post-tensioned reinforced concrete members and the

combining of such members into an integral structure. Prerequisites: Cv Eng 223 with a grade of "C" or better.

329 Foundation Engineering II (Lect 3.0) Classical earth pressure theories. Analysis of shallow and deep foundations to include bearing capacity and settlement of footings, rafts, piles, and drilled piers. Analysis of stability and design of retaining walls and anchored bulkheads. Prerequisites: Cv Eng 229 with a grade of "C" or better.

330 Hydraulic Transients (Lect 3.0) The study of unsteady flow and its effect on closed water distribution systems, water power and irrigation systems. Relationships between unsteady flow and open channel controls. Prerequisites: Cv Eng 230 with a grade of " C" or better.

331 Hydraulics of Open Channels (Lect 3.0) The phenomena accompanying the flow of water in open channels, such as uniform and varied flow, critical conditions, shooting flow, backwater curves, hydraulic jump, drop, and applications are studied in detail. Prerequisites: Cv Eng 230 with a grade of "C" or better.

333 Intermediate Hydraulic Engineering (Lect 3.0) Application of fluid mechanics principles to the design. Kinematics of fluid motion, conservation of mass, linear and angular momentum, and energy. Requirements for similarity of fluid flow. Introduction to dynamics of fluid flows and viscous incompressible flows. Prerequisites: Cv Eng 230 with a grade of "C" or better.

335 Water Infrastructure Engineering (Lect 2.0 and Lab 1.0) Fundamental principles underlying comprehensive water infrastructure development; sanitary sewers, sanitary treatment facilities, stormwater sewers, stormwater detention, water power development, and hydraulic structures. The student is responsible for the planning and design of a water infrastructure development project. Prerequisite: Cv Eng 230 with a grade of "C" or better.

337 River and Harbor Engineering (Lect 3.0) Formation of rivers and the laws governing river regulation and improvements, including navigation and flood protection. Principles governing harbor design. Prerequisites: Cv Eng 230 with a grade of "C" or better.

338 Hydrologic Techniques (Lect 3.0) A study of current up-to-date hydrologic techniques involving design of hydrologic input for bridges, culverts, reservoirs. Techniques involve extreme value statistics, model hydrographs, routing, etc. Prerequisites: Cv Eng 233 with a grade of "C" or better.

341 Professional Aspects of Engineering Practice (Lect 3.0) A study of engineering registration laws, regulations, rules of professional responsibility and standards of practice. Review of causative factors of selected failures and their relationship to professional responsibility. Prerequisite: Senior standing.

345 Construction Methods (Lect 3.0) Introduction to construction planning, selection of equipment and familiarization with standard methods for horizontal and vertical construction. Application of network analysis and schedules to project control. Prerequisite: Cv Eng 248 with a grade of "C" or better.

346 Management of Construction Costs (Lect 3.0) Management of construction projects from inception to completion: estimates, role of network preplanning, project monitoring and control. Prerequisites: Cv Eng 248 with a grade of "C" or better.

349 Engineering and Construction Contract Specifications (Lect 3.0) Legal and business aspects of contracts and contracting procedure in the construction industry to include contracts for engineering services and for construction. Analysis, study of precedents, and application of the more important provisions, including changes, differing site conditions, liability, arbitration, termination, disputes, appeal procedure, payments, insurance, inspection, liquidated damages, and technical provisions. Prerequisite: Preceded or accompanied by Cv Eng 248.

353 Traffic Engineering (Lect 3.0) Driver, vehicle, and roadway characteristics; traffic control devices; traffic studies; intersection capacity, intersection design, traffic safety, and evaluation of traffic improvements. Traffic laws and ordinances, traffic engineering, traffic circulation, parking design, and forecasting traffic impacts. Prerequisites: Cv Eng 211 with a grade of "C" or better.

360 Environmental Law and Regulations (Lect 3.0) This course provides comprehensive coverage of environmental laws and regulations dealing with air, water, wastewater, and other media. The primary focus is permitting, reporting, and compliance protocols. The course topics include U.S. and international legal systems and judicial processes, liability, enforcement, Clean Air Act, Clean Water Act (NPDES) permitting), Safe Drinking Water Act, OSGA, TSCA, RCRA, AND CERCLA. Case studies will be emphasized. (Co-listed with Env En 360)

361 Remediation of Contaminated Groundwater and Soil (Lect 2.0 and Lab 1.0) Course covers current in-situ and ex-situ remediation technologies. Current literature and case studies are utilized to provide the focus for class discussions and projects. Prerequisites: Cv Eng 265, Ge Eng 337 or Graduate Standing. (Co-listed with Env En 361)

362 Public Health Engineering (Lect 3.0) A comprehensive course dealing with the environmental aspects of public health. Prerequisites: Cv Eng 261 with a grade of "C" or better. (Co-listed with Env En 362)

363 Solid Waste Management (Lect 3.0) A systematic study of the sources, amounts and characteristics of solid wastes and methods used for their collection, reclamation, and ultimate disposal. Prerequisites: Cv Eng 261 with grade of "C" or better; or graduate standing. (Co-listed with Env En 363)

365 Environmental Engineering Analysis Laboratory (Lect 1.0 and Lab 2.0) Environmental Engi-

neering analytical principles and techniques applied to the quantitative measurement of water, wastewater and natural water characteristics, and application of advanced instrumental methods in environmental engineering. Prerequisites: Cv Eng 265 with grade of "C" or better; or graduate standing. (Co-listed with Env En 365)

367 Introduction to Air Pollution (Lect 3.0) Introduction to the field of air pollution dealing with sources, effects, federal legislation, transport and dispersion and principles of engineering control. Prerequisite: Cv Eng 230; or graduate standing. (Co-listed with Env En 367)

368 Air Pollution Control Methods (Lect 3.0) Study of the design principles and application of the state-of-the-art control techniques to gaseous and particulate emissions from fossil fuel combustion, industrial and transportation sources. Prerequisite: Cv Eng 230; or graduate standing. (Co-listed with Env En 368)

369 Sanitary Engineering Design (Lect 2.0 and Lab 1.0) Functional design of water and waste water treatment facilities. Prerequisites: Cv Eng 265 with a grade of "C" or better. (Co-listed with Env En 369)

373 Airport Planning and Design (Lect 1.0 and Lab 1.0) Lectures and reports on location, layout, design, construction, operation and maintenance of airports. Design problems assigned. Prerequisites: Cv Eng 211 with a grade of "C" or better.

380 Water Resources and Wastewater Engineering (Lect 3.0) Application of engineering principles to the planning and design of multipurpose projects involving water resources development and wastewater collection/treatment/disposal/systems. Latest concepts in engineering analysis are applied to evaluation of alternative solutions. Prerequisites: Cv Eng 233, 235, 265. (Co-listed with Env En 380)

386 Groundwater Hydraulics (Lect 3.0) A comprehensive study of fundamentals of groundwater hydraulics. Basic hydraulics of confined and unconfined aquifers. Design criteria for well strainers, pumping equipment, and practical aspects of well drilling. Evaluation of water supply based upon consumptive use and other water needs of the community. Hydraulics of recharge wells as affected by storm drains and return water from irrigation. Fundamental treatment of water rights. Integration of groundwater and surface water use. Prerequisites: Cv Eng 233 with a grade of "C" or better.

387 Drainage (Lect 3.0) Soil properties for drainage of agricultural lands. Tile and porous drain system, plastic drains, model studies for drains. Theory of open drain system and introduction to drainage by deep well turbine pumps. Urban and rural drainage. Highway and airport drainage. Prerequisites: Cv Eng 233 with a grade of "C" or better.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six (6) credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

410 Seminar (Variable) Discussion of current topics.

411 Transportation Systems Analysis (Lect 3.0) Concepts and principles fundamental to the planning, design, operation, and management of transportation systems using a systems perspective to transportation problems. Concepts from economics, engineering, operations research, management, psychology, and public policy analysis are used throughout. Topics include linear and non-linear programming, dynamic programming, supply-demand microeconomic framework, analysis of transportation demand, system performance, network equilibrium, simulation and associated case studies. Prerequisite: Cv Eng 353.

412 Numerical Methods in Geotechnical Engineering (Lect 3.0) Survey of computer methods of analyzing complex geotechnical engineering problems. Finite element, finite difference and closed form solution techniques. Existing computer models are used to analyze axially and laterally loaded piles, seepage, consolidation and settlement behavior. Prerequisite: Graduate standing.

413 Soil Dynamics II (Lect 3.0) Theory of vibration, spectral response site-specific response spectra, seismic risk analysis, detailed design of retaining structures, pile and machine foundations, soil structure interaction. Dynamic soil properties, seismic slope, stability analysis problem solving by shake, pilay2, winsliq-1, ddrw-1 research needs.

414 Measurement of Soil Properties (Lect 2.0 and Lab 1.0) Laboratory determination of soil properties with emphasis on practical. Applications of test data. Tests include classification, atterberg limits, consolidation, compaction, triaxial shear tests with pore pressure measurement, and direct shear tests. Preparation of technical reports. Prerequisite: Preceded or accompanied by Cv Eng 315.

415 Advanced Soil Mechanics (Lect 3.0) Advanced topics and recent advances in theoretical soil mechanics. Topics may include stress distribution, failure theories, shear failure in ideal soils, consolidation and settlement, physico-chemical properties, and clay mineralogy. Prerequisite: Cv Eng 315.

416 Soil Stabilization (Lect 3.0) The application of mineralogical and physicochemical principles to soil stabilization problems and stabilization techniques for highway and foundation applications. Prerequisite: Cv Eng 315.

417 Earth Dams and Related Problems (Lect 3.0) The exploration for and selection of site and materials, seepage analysis, slope stability and design, embankment design, compaction, instru-

mentation and construction operations as they pertain to earth and rockfill dams. Prerequisite: Cv Eng 315.

419 Advanced Behavior of Reinforced and Prestressed Concrete (Lect 3.0) Behavior of reinforced and prestressed concrete sections, members and wall/shell-type elements subjected to bending, axial load, shear and torsion. Confinement of concrete. Various truss model theories applicable to main members and strut-tie model applicable to disturbed regions, joints, and connections. Prerequisite: Cv Eng 223 with grade of "C" or better.

420 Advanced Structural Mechanics (Lect 3.0) A study of the basic relationships involved in the mechanics of structures. Topics include basic elasticity, elastic foundations, elastic stability of beams and frames, torsion of thin sections. Prerequisite: Preceded or accompanied by Cv Eng 323.

421 Plastic Analysis and Design of Metal Structures (Lect 3.0) Behavior of engineering materials in the inelastic stress range. Analysis and design of elementary structural members and frames.

422 Analysis and Design of Plates and Shells I (Lect 3.0) Fundamental theories of bending and buckling of plates for practical applications in analysis and design of bridge and building floors, highway and airport pavements, and structural plate components. Shell theory with application to tanks, pressure vessels, shell roofs, and folded plate construction. Prerequisite: Preceded or accompanied by Cv Eng 323.

423 Analysis and Design of Plates and Shells II (Lect 3.0) Buckling of cylindrical shells and spherical and stiffened domes. Analysis of cylindrical barrel roofs and other shapes such as paraboloids and conoids. Finite difference and plastic analysis of plates with complex geometry. Thermal stress analysis in plates and shells. Prerequisite: Cv Eng 422.

424 Structural Dynamics and Earthquake Engineering (Lect 3.0) Behavior of structural materials, elements, and systems under dynamic loads and earthquake excitation; computer methods for response analysis of lumped, consistent, and distributed mass models; eigensolution techniques; design of 2-D and 3-D seismic-resistant structures with current building code.

425 Finite Element Application in Structural Design (Lect 3.0) Concepts of analysis and design. Generalized coordinate models and isoparametric derivations for one, two, and three dimensional elements. Systems with plate and shell elements. Structural instability problems. Elastic and inelastic systems for static and dynamic loads. Studies of computer programs.

426 Advanced Design in Steel and Lightweight Structures (Lect 3.0) A critical evaluation of the theories of design and actual behavior of metal components and their connections. The basis of the development of the pertaining codes will be considered. Prerequisite: Preceded or accompanied by Cv Eng 323.

427 Optimum Structural Design (Lect 3.0) Formulation of optimum design; methods for linear, nonlinear, geometric, and dynamic programming; optimality criterion methods; finite element analysis; applications to reinforced concrete and steel structures subjected to static and dynamic loads; optimal control; computer programs ODSEWS-2D-II and ODRESB-3D. Prerequisite: Preceded or accompanied by Cv Eng 323.

428 Analysis of Nonlinear Structures (Lect 3.0) Inelastic behavior of structural members and connections; formulation of various models for steel and reinforced concrete including elasto-plastic, bilinear, trilinear, Ramberg-Osgood, Cheng-Mertz, and Cheng-Lou; matrix analysis of 2-D and 3-D building structures for geometric and material nonlinearity; dynamic and stability analysis. Prerequisite: Preceded or accompanied by Cv Eng 323.

429 Foundation Engineering III (Lect 3.0) A critical study of modern concepts of foundation engineering including current procedure for the application of soil mechanics principles to the design of foundations, embankments and retaining structures. Case histories will be emphasized with the student making successive design decisions.

431 Advanced Hydraulics and Hydraulic Engineering (Variable) Studies in the field of hydraulic engineering to fit the needs of a particular student or class. Each student makes a complete design of a hydraulic development in one of the following fields; water power, sanitation, river and harbor projects. Prerequisite: Cv Eng 230.

432 Turbulence in Open Channel Flow (Lect 2.0 and Lab 1.0) Origin and basic concepts of turbulence, plane and homogeneous turbulence in open channels, turbulent transport in open channel flow. Considerations of nonhomogeneous and nonisotropic turbulence in open channels. Prerequisites: Cv Eng 331 and 336.

435 Hydraulic Structures (Variable) Gravity, arch, multiple arch, and buttress dams including appurtenances such as spillways, penstocks and gates. Latter part of course is designed to needs of the individual student with applications to river and harbor structures, canal and irrigation structures, and sewage structures. Prerequisites: Cv Eng 223 and 230.

437 Hydraulic Equipment (Variable) Design and placement of reaction and impulse turbines, pumps, measuring devices, gates, valves and appurtenant equipment used in connection with water power, navigation, irrigation and other hydraulic developments. Prerequisites: Cv Eng 230 and Mc Eng 219.

438 Advanced Hydrology (Lect 3.0) A study of methods used in modern hydrologic analysis and design. Items of study include hydrography analysis, maximum possible storm, infiltration, design flood determination and project feasibility. Prerequisite: Cv Eng 233.

439 Similitude and Model Studies (Lect 3.0) The use of models and analogies as aids to engineering design. Principles of dimensional analysis. Application to problems of fluid flow and structures is emphasized. Prerequisite: Math 204.

440 Urban Hydrology (Lect 3.0) Studies of the influence of urban areas on their hydrology. Special emphasis on the principles of spatially varied unsteady flow. Model hydrographs leading toward determination of design storm flow are utilized to obtain information necessary for design of storm sewers, channels, and hydraulic structures common to urban areas. Prerequisite: Cv Eng 233.

442 Construction Administration, Planning and Control (Lect 3.0) Study of construction project development and execution, ranging from preliminary engineering to project turnover. Key topics include bidding strategies, quality control, conceptual estimating, scheduling, progress and cost control, value engineering, safety and construction productivity. Prerequisite: Preceded or accompanied by Cv Eng 345.

445 Advanced Construction Engineering (Lect 3.0) Study of the temporary structures and plant used in construction. Key topics include legal implications, codes and regulations, falsework, slipforming, bridge construction supports, and protection of adjacent facilities. Prerequisite: Preceded or accompanied by Cv Eng 345.

453 Transportation Planning (Lect 3.0) Study of urban development, mobility patterns, and the transportation network. Transportation modeling techniques; transportation control plans to improve air quality; consideration of the transportation disadvantaged; transportation planning in smaller cities and rural areas. Access management and site impact analysis of traffic generators. Prerequisite: Cv Eng 353 or consent of instructor.

460 Chemical Principles in Environmental Engineering (Lect 3.0) The course develops fundamental chemical and physical principles underlying environmental engineering systems including drinking water, groundwater, and wastewater treatment; and natural environmental processes. Topics include adsorption, complex formation, acid-base equilibria, solubility, mass transfer and diffusion, electrochemistry, and chemical kinetics. Prerequisite: Graduate Standing. (Co-listed with Env En 460)

461 Biological Principles in Environmental Engineering Systems (Lect 2.0 and Lab 1.0) Course covers the fundamental biological and biochemical principles involved in natural and engineered biological systems. (Co-listed with Env En 461)

462 Physicochemical Operations in Environmental Engineering Systems (Lect 3.0) Course covers physicochemical operations and design in water, wastewater and aqueous hazardous waste treatment systems including coagulation, precipitation, sedimentation, filtration, gas transfer, chemical oxidation and disinfection, adsorption ion exchange. Prerequisite: Cv Eng 230 or equivalent. (Co-listed with Env En 462)

463 Biological Operations in Environmental Engineering Systems (Lect 3.0) Course covers biological operations and design in water, wastewater and aqueous hazardous waste treatment systems including modeling of biological treatment processes; and design of activated sludge systems, trickling filters, rotating biological contractors, lagoons, nitrification and denitrification, and digestion processes. Prerequisite: Cv Eng 230 or equivalent. (Co-listed with Env En 463)

464 Industrial and Hazardous Waste Treatment (Lect 2.0 and Lab 1.0) Course covers fundamentals of industrial and hazardous wastewater treatment systems and characterization including physical, chemical and biological processes and laboratory pilot plant investigations. (Co-listed with Env En 464)

487 Fluid Mechanics of Porous Solids (Lect 3.0) Properties of fluid systems in porous solids. Statics, dynamics and solutions for problems of flow in fully saturated and unsaturated porous solids. Steady and unsteady flow cases. Similitude for two phase flow in porous solids and theory of models.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

491 Internship (Variable) Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high-level engineering experience consistent with the intent of the doctor of engineering degree.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

499 Case Studies in Civil Engineering (Lect 3.0) This course may be taken as part of a non-thesis graduate program. It will be an in-depth study of a topic selected by the student in concert with his graduate advisor. The product of this work will include a comprehensive term paper or civil engineering design project and include an oral pres-

entation of the student's work. Prerequisite: Graduate standing.

COMPUTER ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

311 Introduction to VLSI Design (Lect 2.0 and Lab 1.0) An introduction to the design and implementation of very large scale integrated systems. Procedures for designing and implementing digital integrated systems, structured design methodology, stick diagrams, scalable design rules, and use of computer aided design tools. Prerequisite: Cp Eng 213.

312 Digital Systems Design Laboratory (Lect 2.0 and Lab 1.0) Experimental studies of problems with high speed digital signals in circuits. Student designs, wires, tests, and programs a microprocessor based single board computer project. A FPGA design is programmed and tested. Prerequisite: Cp Eng 213 or 313.

313 Microprocessor Systems Design (Lect 3.0) The design of digital systems based around microcomputers, microcomputer architecture, logic replacement, hardware vs. software tradeoffs, memory design, timing considerations, input/output design, and total systems design. Prerequisites: Cp Eng 213 and Cp Eng 214.

315 Digital Computer Design (Lect 3.0) Organization of modern digital computers; design of processors, memory systems and I/O units, hardware-software tradeoffs in different levels of computer system design. Prerequisites: Cp Eng 213 and Cp Eng 214.

316 Advanced Microcomputer System Design (Lect 3.0) The design of digital systems based on advanced microprocessors. Introduction to microcomputer logic development systems. I/0 interfaces. Assembly and high level language tradeoffs. Hardware and software laboratory projects required. Prerequisite: Cp Eng 313.

317 Fault-Tolerant Digital Systems (Lect 3.0) Design and analysis of fault-tolerant digital systems. Fault models, hardware redundancy, information redundancy, evaluation techniques, system design procedures. Prerequisites: Cp Eng 111 and Cp Eng 112.

318 Digital System Modeling (Lect 3.0) Digital system modeling for simulation, synthesis, and rapid system prototyping. Structural and behavioral models, concurrent and sequential language elements, resolved signals, generics, configuration, test benches, processes and case studies. Prerequisites: Cp Eng 111 and Cp Eng 112; or Cmp Sc 234.

319 Digital Network Design (Lect 3.0) Simulation-based design of digital networks including local, metropolitan, and wide-area networks. Network standards, performance, trade-off, and simulation tools. Prerequisite: Cp Eng 213 or computer hardware competency.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six (6) credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

391 Computer Engineering Senior Project I (Lab 1.0) A complete design cycle. Working in small teams, students will design, document, analyze, implement, and test a product. Topics include: Iteraton in design, prototyping, group dynamics, design reviews, making effective presentations, concurrent design, designing for test, ethics and standards, testing and evaluation. Prerequisites: Stat 217, Cp Eng 111, Econom 121 or 122, Sp&M S 85, English 160, Cp Eng 213, 214, and a computer organization elective.

392 Computer Engineering Senior Project II (Lab 3.0) A continuation of Cp Eng 391. Prerequisites: Cp Eng 391, Cp Eng 210.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Prerequisite: Consent of the instructor.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course. Variable title. Prerequisite: Consent of the instructor.

404 Data Mining and Knowledge Discovery (Lect 3.0) Data mining and knowledge discovery utilized both classical and new algorithms, such as machine learning and neural networks, to discover previously unknown relationships in data. Key data mining issues to be addressed include knowledge representation and knowledge acquisition (automated learning). Prerequisites: Cmp Sc 304 or 347, Stat 215. (Co-listed with Cmp Sc 404 and Eng Mg 404)

412 Digital Logic (Lect 3.0) Digital logic analysis, synthesis and simulation. Design automation of digital systems. Prerequisites: Cp Eng 111 and Cp Eng 112.

415 Advanced Computer Architecture I (Lect 3.0) Advanced topics in computer structures, parallel processors, and computer networks. Emphasis on their design, applications, and performance. Prerequisite: Cp Eng 313 or Cp Eng 315.

416 Advanced Computer Architecture II (Lect 3.0) Continuation of Computer Engineering 415. Prerequisite: Cp Eng 415.

490 Special Research and Thesis (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Consent of the instructor required.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and

must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except for the dissertation, and are away from the campus, must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

COMPUTER SCIENCE

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

303 Multimedia Systems (Lect 3.0) This course introduces the concepts and components of Multimedia information systems. Topics include: Introduction to Multimedia Data, Multimedia Date Compression, Techniques and Standards, Indexing and Retrieval, Data Storage Organization, Communication and Synchronization, Applications-Media-OnDemand Systems, Video Conferencing, Digital Libraries. Prerequisite: Cmp Sc 153.

304 Data Base Systems (Lect 3.0) Fundamental concepts of data base including a history of development, definition of terms, functional requirements of complex data structures, data base administrator functions, privacy-confidentiality issues, and future directions. Case studies are coordinated with a detailed examination of several commercially available systems. Prerequisites: (Cmp Sc 238 or 274) and Cmp Sc 158.

306 Software Engineering I (Lect 3.0) Development of methodologies useful in the software engineering classical life cycle. This includes: requirements, design, implementation, and testing phases. These methodologies are reinforced through utilization of a CASE tool and a group project. Prerequisite: Cmp Sc 253.

307 Software Testing and Quality Assurance (Lect 3.0) It covers unit testing, subsystem testing, system testing, object-oriented testing, testing specification, test case management, software quality factors and criteria, software quality requirement analysis and specification, software process improvement, and software total quality management. Prerequisite: Cmp Sc 253.

308 Object-Oriented Analysis and Design (Lect 3.0) This course will explore principles, mechanisms, and methodologies in object-oriented analysis and design. An object-oriented programming language will be used as the vehicle for the exploration. Prerequisite: Cmp Sc 253.

310 Seminar (Variable) Discussion of current topics. Prerequisite: Senior standing.

317 Intellectual Property for Computer Scientists (Lect 3.0) A presentation of the relationship between the law of intellectual property and computer science. Topics include the application of copyright principles to computer programs, protection of computer programs through patents and trade secret law, and the effect of various agreements which are frequently encountered by the computer scientist. Prerequisite: Senior or graduate standing.

319 Management of Computing Services (Lect 3.0) A thorough survey of the management of computing facilities and services, including selection and evaluation of hardware and software, cost analysis, scheduling, security, privacy, budgets, documentation, effective programming, system planning, project management and data communications. Prerequisite: Consent of instructor required.

328 Object-Oriented Numerical Modeling I (Lect 3.0) A study of object-oriented modeling of the scientific domain. Techniques and methodologies will be developed enabling the student to build a class library of reusable software appropriate for scientific application. Applications will be drawn from mechanics, finance, and engineering. Prerequisites: Cmp Sc 228 and Cmp Sc 153.

329 Numerical Linear Algebra (Lect 3.0) A survey of the state-of-the-art problem-solving numerical techniques. Topics will include: direct and iterative methods for linear and non-linear equations, optimization, eigenvalue problem finite element methods. Multigrid method, parallel numerical algorithms. Prerequisite: Cmp Sc 228 or Advanced Calculus.

330 Automata Theory (Lect 3.0) Description of the extended Chomsky hierarchy and the relation of Chomsky language classes to grammars automata. Use of languages, grammars and automata in the compilation of programming languages. Introduction to decidability. Prerequisite: Cmp Sc 158.

333 The Structure of a Compiler (Lect 3.0) Review of Backus normal form language descriptors and basic parsing concepts. Polish and matrix notation as intermediate forms, and target code representation. Introduction to the basic building blocks of a compiler: syntax scanning, expression translation, symbol table manipulation, code generation, local optimization, and storage allocation. Prerequisites: Cmp Sc 236 or 274 and Cmp Sc 253 (or graduate standing).

342 Java GUI & Visualization (Lect 3.0) Fundamentals of Java Swing Foundation Classes, Java System Language Specifics, Graphical User Interfaces, Images, Audio, Animation, Networking, and Threading. Visualization of Algorithms. GUI Elements include Event Driven Programming, Interaction with Mouse and KeyBoard, Window Managers, Frames, Panels, Dialog Boxes, Borders. Prerequisite: Cmp Sc 253 or equivalent.

343 Interactive Computer Graphics (Lect 3.0) Applications and functional capabilities of current computer graphics systems. Interactive graphics programming including windowing, clipping, segmentation, mathematical modeling, two and three dimensional transformations, data structures, perspective views, antialiasing and software design. Prerequisite: Cmp Sc 228 and 253.

345 Introduction to Robotic Systems (Lect 3.0) Analysis of methods of the design and operation of robotic systems. Identification of three-dimensional objects using digitized images. Arm control: coordinate transformations, feedback control systems, and hardware components. Applications of distributed micro-computers to robotic control. command languages and job assignments. Prerequisites: Math 22, Physics 24, (Cmp Sc 158 or Cmp Sc 228).

347 Introduction to Artificial Intelligence Programming (Lect 3.0) A study of LISP, PROLOG and other special object oriented computer languages for developing intelligent software. In addition knowledge abstraction and representation, searching, backtracking, recursion, and pruning will be presented. A substantial project in expert systems is required. Prerequisite: Cmp Sc 253.

355 Analysis of Algorithms (Lect 3.0)The purpose of this course is to teach the techniques needed to analyze algorithms. The focus of the presentation is on the practical application of these techniques to such as sorting, backtracking, and graph algorithms. Prerequisite: Cmp Sc 253.

360 Deterministic Modeling (Lect 3.0) The course is an in-depth introduction to the basic building blocks of deterministic modeling using the digital computer. Topics include linear programming and nonlinear programming. Problem analysis and algorithm development and implementation will be covered. Programming project required. Prerequisites: Cmp Sc 228 or Math 203 or 208.

366 Regression Analysis (Lect 3.0) Simple linear regression, multiple regression, regression diagnostics, multicollinearity, measures of influence and leverage, model selection techniques, polynomial models, regression with autocorrelated errors, introduction to non-linear regression. Prerequisites: Math 22 and one of Stat 211, 213, 215, 217, or 343. (Co-listed with Stat 346)

376 Operations Research Techniques for Managerial Decisions (Lect 3.0) Introduction to forecasting techniques, linear programming, queueing theory and computer simulation. Application of the digital computer to the solution of problems in the above areas will be emphasized along with an understanding of the basic theoretical concepts. Offered EEC only. Prerequisite: Math 215 and programming competency. Not open to Cmp Sc majors with emphasis in O.R.

378 Introduction to Neural Networks & Applications (Lect 3.0) Introduction to artificial neural network architectures, adaline, madaline, back propagation, BAM, and Hopfield memory, counterpropagation networks, self organizing maps, adaptive resonance theory, are the topics covered. Students experiment with the use of artificial neural networks in engineering through semester projects. Prerequisite: Math 229 or Math 204 or equivalent. (Co-listed with Eng Mg 378, El Eng 368)

381 The Structure of Operating Systems (Lect 3.0) The hardware and software requirements for operating systems for uniprogramming, multiprogramming, multiprocessing, time sharing, real time and virtual systems. The concepts of supervisors, interrupt handlers, input/output control systems, and memory mapping are discussed in detail. Prerequisite: Cmp Sc 284.

384 Distributed Operating Systems (Lect 3.0) This is a study of modern operating systems, particularly distributed operating systems. Topics include a review of network systems and inter-process communication, causality, distributed state maintenance, failure detection, reconfiguration and recovery, load balancing, distributed file systems, distributed mutual exclusion, and stable property detection including deadlock detection. A group project in Distributed Systems programming will be required. Prerequisites: Cmp Sc 284 and 253.

385 Computer Communications and Networks (Lect 3.0) Network architecture model including physical protocols for data transmission and error detection/correction, data link concepts, LAN protocols, internetworking, reliable end to end service, security, and application services. Students will implement course concepts on an actual computer network. Prerequisites: Cmp Sc 284 and Cmp Sc 158.

387 Parallel Processing: Architectures, Languages and Algorithms (Lect 3.0) Introduction to parallel (concurrent) processing. Topics will include parallel computer architectures, programming languages which support parallel processing and parallel algorithms. Special emphasis will be placed on the design, analysis and implementation of parallel algorithms. Prerequisites: Cmp Sc 284 and Cmp Sc 355 (co-requisite).

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Does not lead to the preparation of a thesis. Not more than six (6) credit hours allowed for graduation credit. Subject and credit to be arranged with the faculty supervisor.

397 Software Systems Development I (Lab 3.0) Class members will work in small teams to develop a complete software system beginning with end-user interviews and concluding with end-user training. Prerequisite: 100 credit hours completed.

398 Software Systems Development II (Lab 3.0) This course is an optional continuation of Cmp Sc 397. Those interested in project management should take this course since participants become officers or group leaders in the class "corporation." This course is especially important for those going straight into industry upon graduation. Stu-

dents with coop experience may find this course redundant. Prerequisite: Cmp Sc 397.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

404 Data Mining & Knowledge Discovery (Lect 3.0) Data mining and knowledge discovery utilizes both classical and new algorithms, such as machine learning and neural networks, to discover previously unknown relationships in data. Key data mining issues to be addressed include knowledge representation and knowledge acquisition (automated learning). Prerequisites: Cmp Sc 304 or 347, Stat 215. (Co-listed with Engineering Management 404 and Computer Engineering 404)

406 Software Engineering II (Lect 3.0) A quantitative approach to measuring costs/productivity in software projects. The material covered will be software metrics used in the life cycle and the student will present topical material. Prerequisite: Cmp Sc 306.

408 Object-Oriented Database Systems (Lect 3.0) This course will include a study of the origins of objectoriented database manipulation languages, their evolution, currently available systems, application to the management of data, problem solving using the technology, and future directions. Prerequisites: Cmp Sc 308 and Database Systems.

410 Seminar (1.0 Hours) Discussion of current topics.

422 Numerical Differential Equations (Lect 3.0) The numerical solution of ordinary and partial differential equations, boundary value problems, eigenvalue problems, stability and convergence of current numerical methods solution of applied problems on digital computers. Prerequisite: Cmp Sc 328 or Cmp Sc 329.

428 Parallel Numerical Linear Algebra (Lect 3.0) A survey of the state-of-the-art computational methods of linear algebra and their parallel implementations; theory of matrices in numerical analysis, direct and iterative methods of solving systems of linear equations, eigenvalue problems, gradient methods, parallel algorithms. Prerequisite: Cmp Sc 328 or Cmp Sc 329.

433 Theory of Compiling (Lect 3.0) Properties of formal grammars and languages, language-preserving transformations, syntax-directed parsing, classes of parsing methods and the grammars for which they are suited, control flow analysis, and the theoretical framework of local and global program optimization methods. Prerequisite: Cmp Sc 333.

435 Theory of Computation (Lect 3.0) Turing machines and other machines. Godel numbering and unsolvability results. Machines with restricted memory access and limited computing time. Recursive functions, computable functionals and the classification of unsolvable problems. Prerequisite: Cmp Sc 330.

443 Computer Graphics and Realistic Modeling (Lect 3.0) Algorithms, data structures, software design and strategies used to achieve realism in computer graphics of three-dimensional objects. Application of color, shading, texturing, antialiasing, solid modeling, hidden surface removal and image processing techniques. Prerequisite: Cmp Sc 343.

445 Robotic Sensors and Controls (Lect 3.0) State-of-the-art topics in robotics control and sensory systems. Robotic sensors: position and proximity sensors, touch, force and torque sensors, and robotic vision implementations. Computer control: robotic software tools and techniques and embedded microprocessors. Prerequisite: Cmp Sc 345.

447 Advanced Topics in Artificial Intelligence (Lect 3.0) Objectives of work in artificial intelligence simulation of cognitive behavior and self-organizing systems. Heuristic programming techniques including the use of list processing languages. Survey of examples from representative application areas. The mind-brain problem and the nature of intelligence. Class and individual projects to illustrate basic concepts. Prerequisite: Cmp Sc 347.

455 Algorithmics II (Lect 3.0) Covers selected classical and recent developments in the design and analysis of algorithms, such as sophisticated data structures, amortized complexity, advanced graph theory, and network flow techniques. Prerequisite: Cmp Sc 355.

466 Stochastic Modeling (Lect 3.0) The course is in-depth introduction to the basic building blocks of stochastic modeling using the digital computer. Topics include simulation, queueing theory, Markovian decision processes, inventory, and forecasting. Problem analysis, algorithm development and implementation will be covered. Programming project required. Prerequisites: Cmp Sc 360, Stat 215.

485 Distributed Systems Theory and Analysis (Lect 3.0) Analysis of the problems of state maintenance and correctness in concurrent systems using formal methods such as Hoare Logic and Temporal Logic applied to agreement problems, serializability theory, and consistency for database systems, file systems, and responsive computing systems. Prerequisites: Cmp Sc 385 or Cmp Sc 387 and Cmp Sc 158.

487 New Trends in Massively Parallel Computing (Lect 3.0) The study of exploiting the potential parallelism of massively parallel computers, state-of-the-art multiprocessor architectures and languages. Topics from current research include design and analysis of efficient parallel algorithms, task partitioning and load balancing, topological embeddings, and reconfigurable mesh algorithms. Prerequisite: Cmp Sc 387.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

ELECTRICAL ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course. Variable title.

303 Electrical Distribution System Design and Protection (Lect 3.0) Analysis of unbalanced faults in distribution systems. Computer methods are used for modeling and calculations, protection devices and their applications, new technologies such as load management and distribution automation are developed and demonstrated. Prerequisite: El Eng 207.

305 Electric Drive Systems (Lect 3.0) Course content is roughly 1/3 power electronics, 1/3 applied control and 1/3 electric machinery and focuses on analysis, simulation, and control design of electric drive based speed, torque, and position control systems. Prerequisites: El Eng 205 and El Eng 231.

307 Power Systems Engineering (Lect 3.0) Network analysis applied to power systems; the load flow concept; economic operation of power systems; synchronous machine reactances and transient stability; symmetrical components and asymmetrical faults; protective relaying. Prerequisite: El Eng 207.

323 Classical Optics (Lect 3.0) Physical optics and advanced topics in geometrical optics. Topics include ray propagation, electromagnetic propagation, mirrors, lenses, interference, diffraction, polarization, imaging systems, and guided waves. Prerequisites: Math 22 and Physics 24 or 25. (Co-listed with Physics 323)

324 Fourier Optics (Lect 3.0) Applications of Fourier analysis and linear systems theory to optics. Topics include scalar diffraction theory, Fourier transforming properties of lenses, optical information processing, and imaging systems. Prerequisites: El Eng 265 & 271 or Physics 208 & 321. (Co-listed with Physics 324)

325 Optical Computing (Lect 0.3) Introduction to the principles, subsystems, and architectures of optical computing. Topics include characteristics of optical devices; optical implementations of memory, logic elements, and processors; and computational structures. Prerequisites: Cp Eng 111 & El Eng 271 or equivalent.

326 Fiber and Integrated Optics (Lect 3.0) Introduction to optical waveguides and their applications to communication and sensing. Topics include dielectric waveguide theory, optical fiber characteristics, integrated optic circuits, coupled-mode theory, optical communication systems, and photonic sensors. Prerequisite: El Eng 271 or Physics 321. (Co-listed with Physics 326)

327 Fiber Optic Communication Systems (Lect 3.0) Ideal and non-ideal optical fibers, transmission characteristics of optical fibers, optical sources, LED and laser sources, modulation formats, direct and external modulation, optical detectors, optical amplifiers, noncoherent and coherent optical recievers, wavelength division multiplexing, system performance. Prerequisites: El Eng 265 and El Eng 253, preceded or accompanied by El Eng 243 and El Eng 225.

329 Smart Materials and Sensors (Lect 2.0 and Lab 1.0) Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multidisciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 204. (Co-listed with Ae Eng, E Mech, Mc Eng 329 and Cv Eng 318)

331 Digital Control (Lect 3.0) Analysis and design of digital control systems. Review of ztransforms; root locus and frequency response methods; state space analysis and design techniques; controllability, observability and estimation. Examination of digital control algorithms. Prerequisites: El Eng 231, 267.

332 Plantwide Process Control (Lect 3.0) Synthesis of control schemes for continuous and batch chemical plants from concept to implementation. Mulitloop control, RGA, SVD, constraint control, multivariable model predictive control, control sequence descriptions. Design project involving a moderately complicated multivariable control problem. Prerequisite: Ch Eng 261 or El Eng 231. (Co-listed with Ch Eng 367)

333 System Simulation and Identification (Lect 3.0) Computationally efficient methods of digital simulation of linear systems. Non-parametric identification. Parametric identification with least squares and recursive least squares algorithms.

Algorithms programmed using MATLAB. Prerequisites: El Eng 231, 267.

337 Neural Networks for Control (Lect 3.0) Introduction to artificial neural networks and various supervised and unsupervised learning techniques. Detailed analysis of some of the neural networks that are used in control and identification of dynamical systems. Applications of neural networks in the area of Control. Case studies and a term project. Prerequisite: El Eng 231.

338 Fuzzy Logic Control (Lect 3.0) A mathematical introduction to the analysis, synthesis, and design of control systems using fuzzy sets and fuzzy logic. A study of the fundamentals of fuzzy sets, operations on these sets, and their geometrical interpretations. Methodologies to design fuzzy models and feedback controllers for dynamical systems. Various applications and case studies. Prerequisite: El Eng 231.

341 Digital Signal Processing (Lect 3.0) Spectral representations, sampling, quantization, z-transforms, digital filters and discrete transforms including the Fast Fourier transform. Prerequisite: El Eng 267.

343 Communications Systems II (Lect 3.0) Random signals and their characterization; noise performance of amplitude, angle and pulse modulation systems; digital data transmission; use of coding for error control. Prerequisite: El Eng 243.

345 Digital Image Processing (Lect 3.0) Fundamentals of human perception, sampling and quantization, image transforms, enhancement, restoration, channel and source coding. Prerequisite: El Eng 267.

347 Machine Vision (Lect 3.0) Image formation, image filtering, template matching, histogram transformations, edge detection, boundary detection, region growing and pattern recognition. Complementary laboratory exercises are required. Prerequisites: Cp Eng 111 and preceded or accompanied by El Eng 267.

351 Advanced Electronic Circuits (Lect 3.0) Linear and nonlinear integrated circuits, feedback amplifiers, oscillators, power amplifiers, power supplies. Prerequisite: El Eng 254.

353 Power Electronics (Lect 3.0) Power semiconductor devices in switching mode converter and control circuits, phase-controlled rectifiers, synchronous inverters, AC regulators, cyclo-convertors; self commutated inverters; and frequency changers; thermal analysis and protection. Applications to industry and HVDC. Prerequisite: El Eng 253.

355 High-Frequency Amplifiers (Lect 3.0) Analysis and design of high frequency amplifiers. Topics include parameter conversions, activity and passivity, stability criteria, device operating conditions, Smith chart usage, matching networks, microstrip, scattering parameters, and practical applications. Prerequisites: El Eng 254, 271.

357 Communication Circuits (Lect 3.0) Analysis and design of circuits used in communication systems. Topics include RF semiconductor devices, low-noise amplifiers, mixers, modulators, crystal oscillators, AGC circuits, highpower RF amplifiers, phase-locked loops, impedence matching, and frequency-selective networks and transformers. Prerequisites: El Eng 254, preceded or accompanied by El Eng 243.

361 Computer-Aided Network Design (Lect 3.0) Analysis and design of active and passive electric networks. Theory and computer application, including methods for automatic formulation of network state equations, network tolerance, network optimization, and device modeling. Prerequisites: El Eng 253, 267.

363 Introduction to Circuit Synthesis (Lect 3.0) Fundamentals of linear circuit theory. Matrix formulation, and topological methods as applied to circuit analysis. Properties of network functions and introductory network synthesis. Prerequisite: El Eng 267.

368 Introduction to Neural Networks & Applications (Lect 3.0) Introduction to artificial neural network architectures, adaline, madaline, back propagation, BAM, and Hopfield memory, counterpropagation networks, self organizing maps, adaptive resonance theory, are the topics covered. Students experiment with the use of artificial neural networks in engineering through semester projects. Prerequisite: Math 229 or Math 204 or equivalent. (Co-listed with Eng Mg 378, Cmp Sc 378)

371 Grounding and Shielding (Lect 3.0) Fundamental principles involved in typical grounding and shielding problems, objectives and techniques for grounding and shielding to reduce misconceptions and a more systematic approach to replace "trial and error" methods, interference mechanisms and shielding techniques. Prerequisites: El Eng 265 and 271.

373 Antennas and Propagation (Lect 3.0) Propagated fields of elemental dipole, directivity and gain, radiation resistance, the half-wave dipole, wire antennas, arrays, broadband antennas, aperture antennas, horn antennas, and antenna temperature. Prerequisite: El Eng 271.

377 Microwave Circuit Design (Lect 3.0) Computer-aided design of microwave circuits such as couplers, isolators, circulators, mixers, filters, switches, quadrature hybrids, amplifiers, oscillators and microstrip antennas using industry-standard software packages. Microwave integrated circuits. Emphasis on industrial applications. Prerequisites: El Eng 253, 271.

379 Microwave Theory and Techniques (Lect 3.0) Microwave systems; coupled transmission lines, waveguides and resonators; klystron, magnetron and traveling wave tubes; microwave integrated circuits and semiconductor devices. Prerequisite: El Eng 271.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six (6) credit hours allowed for gradu-

ation credit. Subject and credit to be arranged with the instructor.

391 Electrical Engineering Senior Project I (Lab 1.0) A complete design cycle. Working in small teams, students will design, document, analyze, implement and test a product. Topics include: Iteration in design, prototyping, group dynamics, design reviews, making effective presentations, concurrent design, designing for test, ethics and standards, testing and evaluation. Prerequisites: Stat 217, Cp Eng 111, Econom 121 or 122, Sp&M 85, English 160, at least 3 of the following: El Eng 205, El Eng 207, El Eng 265, El Eng 267, El Eng 271, El Eng 254.

392 Electrical Engineering Senior Project II (Lab 3.0) A continuation of El Eng 391. Prerequisites: El Eng 391, El Eng 210.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

402 Advanced Theory of Electric Machines (Lect 3.0) Energy conversion, reference frame theory, transient and dynamic modeling of ac machines, simulation of ac machines, parameter identification, model-order reduction, advanced topics depending on semester taught. Prerequisite: El Eng 205.

403 Power System Reliability (Lect 3.0) Reliability definition and measures. Probability concepts and Markov chains. Failure models and availability models. Generator system reliability. Loss of load probability method. Evaluation of transmission network reliability. Analysis of the electric power system reliability. Prerequisite: Stat 343 or El Eng 343.

404 Economic Operation of Power Systems (Lect 3.0) Optimum economic loading of thermal plants determined by the method of Lagrange multipliers, derivation of the system loss matrix and its transformation to the most useful basis, practical evaluation of the matrix elements, extension of optimum loading criteria to include system losses, effect of hydro plants on system economics. Prerequisite: El Eng 307.

405 Power System Protection (Lect 3.0) Protective relaying incorporating electromechanical, solid state and modern computer relaying methods for high voltage transmission systems. Pilot wire, power line carrier apparatus, bus protection, circuit breaker interruption characteristics, out of step relaying, reclosing, synchronizing, load and frequency relaying. Prerequisite: El Eng 303 and 307

406 Power System Stability (Lect 3.0) Synchronous machine theory and modelling; AC transmission; power system loads; excitation systems; control of active and reactive power; small signal stability; transient stability; voltage stability; mid-term and long-term stability; sub-synchronous oscillations; stability improvement. Prerequisite: El Eng 207 or similar course.

407 Surge Phenomena in Power Systems (Lect 3.0) Study of transmission system insulation, distributed constant lines, terminations, multiple reflections, lighting performance, characteristics of sustained and switching overvoltages, surge voltages due to system faults, energizing and reclosing of circuit breakers. Methods of reducing overvoltages to acceptable levels. Prerequisite: El Eng 307.

408 Computer Methods in Power System Analysis (Lect 3.0) Algorithms of power-network matrices, three-phase networks, short-circuit, load-flow and transient stability studies by computer methods. Prerequisite: El Eng 207 or similar course.

420 Semiconductor Devices (Lect 3.0) Properties of semiconductors, junctions and transistors; high frequency and high-current effects; recombination processes; field-effect devices, semiconductor devices and microcircuits. Prerequisite: Graduate status in El Eng.

421 Solid State Electronics (Lect 3.0) Advanced topics in semiconductor, dielectric, magnetic, and optical processes and devices. Semiconductor electronics, materials and devices; dielectric and magnetic processes with applications to devices; optical phenomena with application to devices. Prerequisite: Graduate status in El Eng.

423 Optical and Quantum Electronics (Lect 3.0) Photoelectronic materials, effects and devices. Luminescence of solids; injection-type lasers; incoherent light emitting semiconductor diodes; photovoltaic, dember and related effects; photo-conductivity; use of impurities to sensitize photoconductors. Prerequisite: Graduate status in El Eng.

424 Gaseous Electronics (Lect 3.0) A study of the behavior of charged particles in gases under the influence of electric and magnetic fields including a study of theoretical and experimental results of investigations of mobility, diffusion, attachment and recombination, leading to a discussion of the discharge process. Both microscopic and macroscopic behavior are considered. Prerequisite: El Eng 271.

425 Electromagnetic Optics (Lect 3.0) Propagation, control, and modulation of laser radiation. Topics include optical polarization, interference, layered and anisotropic media, electro-optic devices, acousto-optic devices, and nonlinear optics. Prerequisite: El Eng 271 or Physics 321.

431 Linear Control Systems (Lect 3.0) Review of linear algebra, state variable formulations, solutions of state equations; controllability and observability; multivariable systems, matrixfraction decompositions; design of state and output feedback controllers and observers; introduction to calculus of variations; linear quadratic regulators. Prerequisite: El Eng 231.

432 Optimal Control and Estimation (Lect 3.0) Review of linear quadratic regulators (LQR), LQR extensions; constrained optimization (Pontragin's minimum principle); review of probability theory and random processes; optimal prediction and fil-

ters; frequency domain properties of LQR and Kalman filters; linear quadratic Gaussian (LQG) control; model uncertainties, frequency shaping, LQG/LTR design methodology. Prerequisite: El Eng 431.

433 Current Topics in Control Theory (Lect 3.0) Topics of current interest in control theory literature. Offered as interest and demand warrant. Prerequisite: El Eng 435.

434 Nonlinear Control Systems (Lect 3.0) Numerical solution methods, describing function analysis, direct and indirect methods of Liapunov stability, applications to the Lure problem - Popov circle criterion. Applications to system design and feedback linearizations. Prerequisite: El Eng 431.

438 Robust Control Systems (Lect 3.0) Performance and robustness of multivariable systems, linear fractional transformations, LQG/LTR advanced loop shaping, Youla parameterization, H (subscript infinity) optimal control, mixed H (subscript 2) and H (subscript infinity) control, controller synthesis for multiple objective optimal control, linear matrix inequalities theory and case studies. Prerequisite: El Eng 435.

441 Digital Signal Processing II (Lect 3.0) Continuation of El Eng 341. Effects of discrete noise sources in digital signal processing; discrete spectral analysis of random signals; discrete time signal detection, estimation, and filtering algorithms. Prerequisites: El Eng 341 and 343 or 443 or Stat 343.

443 Statistical Signal Analysis (Lect 3.0)Probability and random processes, correlation functions, power spectral density, orthogonal series expansions of random processes, linear systems with random inputs, weiner and matched filters, nonlinear systems with random inputs. Prerequisite: El Eng 243.

445 Statistical Decision Theory (Lect 3.0) Classical detection and estimation theory with applications; hypothesis testing, detection of known signals, matched filter receiver implementation, detection of signals with unknown parameters, sequential and nonparametric detection, detection of stochastic signals: Parameter estimation theory with application to modulation. Prerequisite: El Eng 443.

447 Information Theory and Coding (Lect 3.0) Principles of information generation, transmission and processing; quantitative measure of information, entropy source encoding; channels; mutual information; channel capacity; Shannon's second theorem for discrete channels; introduction to coding for error controls; continuous information sources. Prerequisites: El Eng 343 or El Eng 443 or Stat 343.

448 Advanced Topics in Communications (Lect 3.0) Advanced topics of current interest in communications and signal processing such as spread spectrum, digital processing of communications, speech, and radar signals, applications of pattern recognition, communications networks, specialized coding topics. Repeatable for additional credit toward degree each time a different subtitle offered. Prerequisite: El Eng 343 or 443.

459 Linear Active Network Theory (Lect 3.0) Linear network theory as applied to networks containing active electronic devices. Special attention given to network structure, reciprocity, stability, feedback, and oscillators. Prerequisite: El Eng 363.

463 Passive Network Synthesis (Lect 3.0) Advanced topics in passive network synthesis. One-port, two-port and n-port network synthesis. Prerequisite: El Eng 363.

464 Active Network Synthesis (Lect 3.0) Active network elements, synthesis of one-port, two-port and n-port networks containing active network elements. Prerequisite: El Eng 363.

467 Distributed Network Theory (Lect 3.0) Analysis of uniform and tapered distributed networks. Synthesis and design of networks containing distributed network elements. Stability and integrated circuit application. Prerequisite: El Eng 363.

471 Advanced Electromagnetics I (Lect 3.0) Review of Maxwell's equations, constitutive relations, and boundary conditions. Wave propagation and polarization. Vector magnetic and electric potentials. Equivalent representations of fields, Babinet's principle. Circular waveguides. Green's functions. Prerequisites: Physics 321 or El Eng 271, Math 325.

473 Electromagnetic Waves II (Lect 3.0) Circular waveguides, circular cavities, scattering by cylinders, apertures in cylinders, spherical cavities, orthogonality relationships, source of spherical waves, scattering by spheres, perturbational and variational techniques, microwave networks, probes in cavities, and aperture coupling to cavities. Prerequisite: El Eng 471.

474 Computational Electromagnetics (Lect 3.0) Differential-equation based numerical methodsfinite element, finite-difference, and finite-difference time-domain-for solving static and dynamic equations of electromagnetics. Applications considered are multi-conductor transmission lines, Maxwell's equations for radiation and scattering, and electric machinery. Prerequisite: El Eng 271.

475 High-Speed Digital Design (Lect 3.0) Techniques for designing and building high-speed digital circuits on printed circuit boards or multi-chip modules. Component and package selection, power bus design, decoupling, parasitic elements, grounding, shielding, and high-speed measurement techniques. Prerequisite: El Eng 271.

490 Special Research and Thesis (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

491 Internship (Variable) Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering ex-

perience consistent with the intent of the doctor of engineering degree.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

ENGINEERING MANAGEMENT

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

308 Economic Decision Analysis (Lect 3.0) Comprehensive treatment of engineering economy including effects of taxation and inflation; sensitivity analysis; decisions with risk and uncertainty; decision trees and expected value, normally includes solutions on personal computer and student problem report. Prerequisite: Graduate students without previous course in engineering economy because of partial overlap.

311 Human Factors (Lect 3.0) An examination of human-machine systems and the characteristics of people that affect system performance. Topics include applied research methods, systems analysis, and the perceptual, cognitive, physical and social strengths and limitations of human beings. The focus is on user-centered design technology, particularly in manufacturing environments. Prerequisite: Psych 50. (Co-listed with Psych 311)

313 Managerial Decision Making (Lect 3.0) Individual and group decision making processes and principles for engineers and technical managers with emphasis on the limitations of human rationality and the roles of social influence and organizational contexts; principles and skills of negotiation. Prerequisite: Senior or graduate standing.

314 Management for Engineers (Lect 3.0) The transition of the engineer to manager; planning and organizing technical activities; selecting and managing projects; team building and motivation; techniques of control and communication; time management. Prerequisite: Senior or graduate standing; students who have taken Eng Mg 211 cannot enroll in this course.

317 Comparative and Multi-National Management (Lect 3.0) To provide management knowledge of multinational business and entrepreneur skills for technically oriented students to manage innovative technologies in a global setting. Prerequisite: Senior or graduate standing.

320 Technical Entrepreneurship (Lect 3.0) Student teams develop a complete business plan for a company to develop, manufacture and distribute real technical/product service. Lectures & business fundamentals, patents, market/ technical forecasting, legal and tax aspects, venture capital, etc., by instructor and successful technical entrepreneurs. Prerequisite: Senior or graduate standing.

322 Accounting for Engineering Management (Lect 3.0) Study of accounting principles, procedures, and the application of accounting principles to management planning, control and decision making. Includes financial statement analysis and cost and budgetary procedures.

324 Fundamentals of Manufacturing (Lect 2.0 and Lab 1.0) This course provides a comprehensive treatment of topics of concern to the Manufacturing Engineer. The effect of manufacturing processes on product design and cost is discussed, and an introduction to inspection and quality control is presented. Prerequisite: Eng Mg 282.

327 Legal Environment (Lect 3.0) Study of the effect of the legal environment on the decisions which the engineering manager must make. The course investigates the social forces that produced this environment and the responsibilities incumbent upon the engineer.

328 Government Regulations; Business & Industry (Lect 3.0) A course which presents the administrative process of government and its present day relationships to the business and industrial world through regulations. Prerequisite: Senior or graduate standing.

330 Industrial Ecology (Lect 3.0) Effective Managerial decision making in manufacturing or service sectors requires familiarity with industrial activities, their impacts on environmental processes and societal interactions. This course will describe interactions between environment and economy. Prerequisite: Stat 213 or 215.

332 Engineering Cost Accounting (Lect 3.0) Analysis and design of job, process and standard cost accounting methods in manufacturing environment, interrelationship of cost accounting methods, and justification of automation in a technological setting. Prerequisite: Senior or graduate standing.

333 Management Information Systems (Lect 3.0) Study of the operational and managerial information needs of an organization. Emphasis is on the information needed throughout an organization and on information systems to meet those needs. Prerequisite: Senior or graduate standing.

334 Computer Integrated Manufacturing Systems (Lect 2.0 and Lab 1.0) Study of the design and use of computer-based integrated manufacturing management systems in the allocation and control of plant, equipment, manpower, and materials. Prerequisite: Eng Mg 282.

335 Labor Management Relations (Lect 3.0) Orientation on labor law. Emphasizes history and development of the federal labor statutes. Gives basic understanding of organizational and operational procedures of unions in conjunction with the legal techniques employed by labor and management. Prerequisite: Senior or graduate standing.

344 Interdisciplinary Problems in Manufacturing Automation (Lect 1.0 and Lab 2.0) Introduction to basic techniques and skills for concurrent engineering, manufacturing strategies, product design, process planning, manufacturing data management and communication are the topics covered. Students experiment the design process through team projects and structured manufacturing laboratory work. Prerequisite: Eng Mg 334. (Co-listed with Mc Eng 344, Ch Eng 344)

345 Energy Management Engineering (Lect 2.0 and Lab 1.0) Appraisal of energy conservation management, economic efficiency of energy sources, and energy productivity analysis. Principles of energy efficiencies and energy balance analysis interfaced with engineering management theory. Prerequisite: Senior or graduate standing.

350 Integrated Product Development (Lect 2.0 and Lab 1.0) Students in design teams will simulate the industrial concurrent engineering development process. Areas covered will be design, manufacturing, assembly, cost, and product support. Using a 3-D solid modeling program, students will design, analyze, and send the data base to the automated machine shop where the parts will be manufactured. The parts will then be assembled, tested and analyzed for their performance. Prerequisites: Ae Eng 251 or Mc Eng 208 for Design; Mc Eng 213 for Assembly; Accompanied or preceded by Mc Eng 353 for Manufacturing; Eng Mg 375 or 385 for Cost/Product Support. (Co-listed with Ae Eng 350 and Mc Eng 350)

351 Industrial Marketing Systems Analysis (Lect 3.0) An analysis of the factors of engineered products, customers, communication, promotion, personal selling, persuasion and management within a dynamic industrial sales environment.

352 Activity Based Accounting and Financial Decision Making (Lect 3.0) This course reviews the fundamentals of activity based accounting and financial decision making.

354 Integrated Product/Process Design (Lect 3.0) Emphasize design policies of concurrent engineering and teamwork, and documenting of design process knowledge. Integration of various product realization activities covering important aspects of a product life cycle such as "customer" needs analysis, concept generation, concept selection, product modeling, process development, DFX strategies, and end of product life options. Prerequisite: Senior or graduate standing.

356 Industrial System Simulation (Lect 3.0) Simulation modeling of manufacturing and service operations through the use of computer software for operational analysis and decision making. Prerequisite: Stat 213 or 215.

357 Advanced Facilities Planning & Design (Lect 1.0 and Lab 2.0) Development of an integrated approach to the planning and design of facilities; examination of advanced techniques and tools for facility location, space allocation, facility layout materials handling system design, work place design; e.g. mathematical programming, simulation modeling, CAD systems, ergonomics. Prerequisite: Eng Mg 257 or instructor's permission.

361 Project Management (Lect 3.0) Organization structure and staffing; motivation, authority and influence; conflict management; project planning; network systems; pricing, estimating, and cost control; proposal preparation; project information systems; international project management. Prerequisite: Eng Mg 211.

363 Environmental and Solid Waste Issues in Packaging (Lect 3.0) Packages which are currently very successful in meeting the environmental challenges shall be contrasted against those which are not as successful. The design criteria for the development of environmentally friendly packaging as well as current issues shall be examined. Prerequisites: Junior or senior standing.

364 Value Analysis (Lect 3.0) An organized effort directed at analyzing the hardware and processes used in manufacturing a product to achieve the required product function at the lowest overall cost. Covers the basic philosophy, methodology and procedures which draw together and utilize techniques from various fields. It is a logical method used in solving value problems. Prerequisite: Senior or graduate standing.

366 Business Logistics Systems Analysis (Lect 3.0) An analysis of logistics function as a total system including inventory, transportation, order processing, warehousing, material handling, location of facilities, customer service, and packaging with trade-off and interaction. Prerequisite: Stat 213 or 215.

368 System Engineering and Analysis I (Lect 3.0) The concepts of Systems Engineering are covered. The objective is to provide the basic knowledge and tools of transforming an operational need into a defined system configuration through the iterative process of analysis, system integration, synthesis, optimization and design. Prerequisite: Graduate or senior standing.

372 Production Planning and Scheduling (Lect 3.0) Introduction to basic techniques of scheduling, manufacturing planning and control, just-in-time systems, capacity management, master production scheduling, single machine processing, constructive Algorithms for flow-shops, schedul-

ing heuristics, intelligent scheduling systems are the topics covered. Prerequisite: Eng Mg 282.

374 Engineering Design Optimization (Lect 3.0) This course is an introduction to the theory and practice of optimal design as an element of the engineering design process. The use of optimization as a tool in the various stages of product realization and management of engineering and manufacturing activities is stressed. The course stresses the application of nonlinear programming methods. Prerequisite: Math 204 or 229.

375 Total Quality Management (Lect 2.0 and Lab 1.0) Examination of various quality assurance concepts and their integration into a comprehensive quality management system: statistical techniques, FMEA's, design reviews, reliability, vendor qualification, quality audits, customer relations, information systems, organizational relationships, motivation. Prerequisite: Senior or graduate standing.

376 Introduction to Quality Engineering (Lect 3.0) This course is an introduction to the theory and practice of quality engineering with particular emphasis on the work of Genichi Taguchi. The application of the quality loss function, signal to noise ratio and orthogonal arrays is considered in-depth for generic technology development; system, product and tolerance design; and manufacturing process design. The emphasis of the course is off-line quality control. Other contributions in the field are also considered. Prerequisite: Eng Mg 375.

377 Expert Systems in Manufacturing & Engineering (Lect 3.0) Intelligent engineering system design using knowledge bases, knowledge based problem solving, symbolic models, knowledge representation, inferencing are the topics covered. Students develop these skills through semester projects based on a specific engineering application using an expert system shell of their choice. Prerequisite: Graduate or senior standing.

378 Introduction to Neural Networks & Applications (Lect 3.0) Introduction to artificial neural network architectures, adaline, madaline, back propagation, BAM, and Hopfield memory, counterpropagation networks, self organizing maps, adaptive resonance theory, are the topics covered. Students experiment with the use of artificial neural networks in engineering through semester projects. Prerequisite: Math 204 or 229. (Co-listed with Cmp Sc 378, El Eng 368)

379 Packaging Machinery (Lect 2.0 and Lab 1.0) Examination and evaluation of packaging machinery as a subset of the packaging system and its relation to the total production and marketing system. Determination of criteria for selection, design and implementation of packaging machinery and systems into the production facility. Prerequisite: Sr standing in engineering.

380 Work Design (Lect 3.0) Addresses the design of workstations and tasks. Topics include micromotion, operational analysis, manual material handling, workstations organization, macroergonomics, anthropometrics, biomechanics, cumulative trauma disorders, handtool design, controls/displays design, work sampling, stopwatch time studies, predetermined time standard systems, and time allowances. Prerequisite: Senior or graduate standing.

381 Management and Methods in Reliability (Lect 3.0) Study of basic concepts in reliability as they apply to the efficient operation of industrial systems. Prerequisite: Stat 213 or 215 or 343.

382 Methods of Industrial Engineering (Lect 2.0 and Lab 1.0) Topics to be covered will include the types of problems frequently encountered by industrial engineers, their impact on the management of an industrial concern, and an exposure to the industrial engineering techniques available to solve problems. Prerequisite: Stat 213 or 215.

383 Packaging Management (Lect 3.0) Provides a comprehensive background in the field of packaging and its place in productive systems. Emphasizes the design or economics of the system. Analyzes the management of the packaging function and interrelationship with other functions of an enterprise.

384 Packaging Materials I (Lect 3.0) The objective is to explore in depth the major packaging materials used by industry and to give the student an understanding of material characteristics, application, economics, design consideration and their relationship in the total productive system. Prerequisite: Eng Mg 383.

385 Statistical Process Control (Lect 3.0) The theoretical basis of statistical process control procedures is studied. Quantitative aspects of SPC implementation are introduced in context along with a review of Deming's principles of quality improvement and a brief introduction to sampling inspection Prerequisite: Stat 213 or 215.

386 Safety Engineering Management (Lect 3.0) This course is an introduction to the principles of safety engineering applied to industrial situations. Job safety analysis, reduction of accident rates, protective equipment, safety rules and regulations, environmental hazards, health hazards, and ergonomic hazards are covered. Prerequisite: Senior or graduate standing.

387 Experimentation in Engineering Management (Lect 3.0) The techniques for planning and analyzing industrial experiments are introduced with emphasis on their application to the design, development, and production of quality goods and services. Prerequisite: Stat 213 or Stat 215.

388 Packaging System Design (Lect 3.0) A study of packaging design problems related to the packaging system through case studies. Emphasizes problem solving techniques using latest materials, technologies, marketing and distribution processes to develop and design a total packaging system. Prerequisite: Eng Mg 383.

389 Packaging Materials II (Lect 2.0 and Lab 1.0) This course is an extension of Eng Mg 384 (packaging materials). The objective is to provide in-

depth treatment of material and systems not covered in 384. Prerequisite: Eng Mg 383.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six (6) credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor. Consent of instructor required.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

404 Data Mining and Knowledge Discovery (Lect 3.0) Data mining and knowledge discovery utilizes both classical and new algorithms, such as machine learning and neural networks, to discover previously unknown relationships in data. Key data issues to be addressed include knowledge representation and knowledge acquisition (automated learning). Prerequisites: Cmp Sc 304 or 347, Stat 215. (Co-listed with Cmp Sc 404 and Cp Eng 404)

408 Advanced Engineering Economy (Lect 3.0) The analyses of capital expenditures, multioutcome considerations: risk and uncertainty, and cost of risk. The study of utility theory, dispersed service lives, expansion and economic package concepts, implementation, control, and followup of capital expenditures, mathematical programming, uncertainty, game theory, model building and simulation, queueing evaluations for capital planning. Prerequisite: Eng Mg 209 or 308.

410 Seminar (Variable) Discussion of current topics.

420 Technological Innovation Management (Lect 3.0) Technological innovation is new technology creating new products and services. This course studies the issues of managing technological innovation under four topics: 1) Innovation; 2) New Ventures; 3) Corporate Research & 4) R&D Infrastructure. Prerequisite: Eng Mg 314.

433 Advanced Management Information System (Lect 3.0) Advanced topics in management information systems such as information resource management, group decision support systems, knowledge based systems, and communication systems. Prerequisite: Eng Mg 333.

434 Advanced Manufacturing Systems Integration (Lect 2.0 and Lab 1.0) The integration of new technology and information processing concepts for controlling the manufacturing systems. Advanced topics in computer integrated manufacturing systems, industrial robots, CNC machine tools, programmable controllers, material handling systems, manufacturing planning and control. Prerequisite: Eng Mg 334.

438 Industrial Queueing Theory (Lect 3.0) Mathematical methods for modeling and analysis of queueing systems using probability theory. Topics include: counting processes, discrete-time processes, single and multiple server queues and Markovian queueing processes. Prerequisites: Eng Mg 382, Stat 213 or equivalent. (Co-listed with Stat 438)

441 Case Studies in General Management (Lect 3.0) A quantitative study of engineering management problems related to the functioning of the industrial enterprise through case studies. Prerequisite: Preceded or accompanied by an Eng Mg 400 level course.

451 Advanced Marketing Management (Lect 3.0) Study of marketing decision areas in the technically based firm, including product selection and development, marketing research, market development, distribution, advertising, and promotion. Pricing policies including legal aspects and problems in selecting, training and controlling field sales force. Examination of interaction within consumer and industrial marketing environments. Prerequisites: Eng Mg 314, Econ 122.

452 Advanced Financial Management (Lect 3.0) Principles of financial organization and management in the technological enterprise; demands for funds; internal and external supply of funds; budgetary control; reserve and dividends policy. Emphasizes systems approach and problems of engineering design and automation as they influence financial decisions. Prerequisite: Eng Mg 322.

454 Advanced Production Management (Lect 3.0) Examination of responsibilities of production manager in the technological enterprise for providing finished goods to meet the quality, price, quantity and specification needs of the market place. Study of functions of production manager. Quantitative approach to decision making in production management. Prerequisites: Senior or graduate standing and advanced mathematical modelling competence.

456 Advanced Personnel Management (Lect 3.0) Current practices of procurement and maintenance of technical personnel in research, development, and design organizations. Adaptation of such personnel to the technological enterprise, current practices in personnel administration, labor management relationships. Prerequisite: Eng Mg 314.

462 Inventory Strategies (Lect 3.0) Topics to be covered will include the nature of inventory systems and the types of management problems encountered in the operation of such systems. Deterministic models with (and without) typical industrial constraints will be examined along with periodic review models with stochastic demands. Prerequisite: Stat 215 or Stat 343.

465 Mathematical Programming (Lect 3.0) Techniques for modeling decision-making problems using appropriate mathematical models of linear, integer, combinatorial, or nonlinear programming. Modeling techniques will be illustrated with examples. A comprehensive treatment of applicable algorithms to solve wide varieties of mathematical programming models will be provided. Prerequisites: Stat 213 or equivalent and (Eng Mg 382 or Math 203 or Math 208) (Co-listed with: Math 465)

468 Systems Engineering Analysis II (Lect 3.0) Advanced concepts of Systems Engineering is covered. The objective is to provide the advanced knowledge and tools of transforming an operational need into a defined system configuration through the iterative process of analysis, system integration, synthesis, optimization and design. These tools and concepts are reinforced with projects and case studies. Prerequisite: Graduate standing.

469 Systems Architecturing (Lect 3.0) The objective of the course is to provide the basic tools and concepts of systems architecting for complex systems design and operations. The following topics are covered; The need for the architect and architecting teams, The process of architecting, Architecting methods, Design of architects, The Architect's Role during System life Cycle. Prerequisite: Graduate standing.

475 Quality Engineering (Lect 3.0) This course is an examination of the theory and practice of quality engineering with particular emphasis on the work of Genichi Taguchi. The application of the quality loss function, signal to noise ratio and orthogonal arrays is considered indepth for generic technology development; system, product and tolerance design; and manufacturing process design. The emphasis of the course is off-line quality control. Prerequisites: Eng Mg 375 and Math 229 or equivalent.

476 Advanced Engineering Management Science (Lect 3.0) Solving of managerial problems utilizing management science techniques. Problems are analyzed, modeled and solved using such techniques as linear, goal, dynamic, programming, simulation, statistical analysis or other nonlinear methods. Solutions will involve the use of personal or mainframe computers. A study of the current literature in management science will also be conducted. Prerequisite: Eng Mg 382 or graduate standing.

478 Advanced Neural Networks (Lect 3.0) Intelligent system architectures, advanced neural networks paradigms; ARTMAP, CMAC, fuzzy logic, associative memory, hierarchical networks, radial basis functions, adaptive heuristic critic for solving product design, process planning and control, scheduling, feature identification and assembly problems in building autonomous manufacturing systems. Prerequisite: Eng Mg 378 or equivalent neural network course.

479 Smart Engineering System Design (Lect 3.0) The course covers the emerging technologies for the design of Smart Engineering Systems, namely; evolutionary programming, fuzzy logic, wavelets, chaos and fractals are introduced. Integration of these techniques for designing Smart Engineering Systems are stressed through a design project. Prerequisite: Eng Mg 378 or equivalent neural network course.

485 Advanced Topics in Quality Assurance (Lect 3.0) Selected topics such as cost analysis, organizational structure, Ishikawa diagrams, Pareto-analysis, Taguchi methods and other statistical procedures will be examined with regard to their underlying theoretical basis and problems in application Prerequisite: Eng Mg 375 or 385 or 387.

489 Advanced Research Methodology in Engineering Management (Lect 3.0) An advanced study of research methodology techniques and theories in conducting research activities. The research problems, hypotheses, literature search, data requirements and analyses, interpretation and presentation of results are examined. Prerequisite: Graduate standing.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

ENGINEERING MECHANICS

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

303 Industrial Applications of Composite Materials Technology (Lect 1.0) Composite materials-industrial applications. Fibers and matrices. Fabrication and NDI. Lamination theory overview. Composite joints. Postbuckling. Fatigue and environmental effects. Testing and certification of composite structures. A majority of the presentations will be made by engineers in the industry. Prerequisite: Bas En 110. (Co-listed with Mc Eng 383)

305 Applications of Numerical Methods to Mechanics Problems (Lect 3.0) Numerical solutions of statics, vibrations and stability problems. Direct stiffness formulations are developed and user oriented computer codes are used to solve practical structures problems. Computer graphics techniques are utilized to prepare data and display results. Prerequisites: Bas En 110, Bas En 150 or E Mech 160. (Co-listed with Mc Eng 314)

307 Finite Element Approximation I - An Introduction (Lect 3.0) Variational statement of a problem, Galerkin approximation, finite element basis functions and calculations, element assemble, solution of equations, boundary conditions, interpretation of the approximate solution, development of a finite element program, two-dimensional problems. Prerequisite: Math 204. (Co-listed with Mc Eng 312, Ae Eng 352)

310 Seminar (Variable) Discussion of current topics. Prerequisite: Senior standing.

311 Introduction to Continuum Mechanics (Lect 3.0) Introductory cartesian tensor analysis to aid in the development of the theory of a continuum. Kinematics of deformation, stress tensor, equations of motion, equations of mass and energy balance. Examples from specific material theories in solid and fluid mechanics. Prerequisites: Bas En 110, Math 204. (Co-listed with Mc Eng 311)

321 Intermediate Mechanics of Materials (Lect 3.0) Continuation of first course in mechanics of materials. Topics to include: theories of failure, torsion of noncircular sections, shear flow, shear center, unsymmetrical bending, bending of curved members and pressurization of thick walled cylinders. Prerequisites: Bas En 110, Math 204.

322 Introduction to Solid Mechanics (Lect 3.0) Review of basic concepts in continuum mechanics. Finite elasticity: some universal solutions for isotropic materials; application of special mechanical models. Linear elasticity: compatibility, stress functions, superposition, special examples such as extension, torsion, bending and plane problems. Elements of plasticity. Prerequisite: E Mech 311. (Co-listed with Ae Eng 322, Mc Eng 322)

324 Engineering Plasticity I (Lect 3.0) The stress-strain relations of materials loaded beyond the elastic range. Yield criteria. Applications to tension, bending, and torsion and their interaction, and to problems with spherical or cylindrical symmetry. Prerequisite: Bas En 110.

329 Smart Materials and Sensors (Lect 2.0 and Lab 1.0) Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multidisciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 204. (Co-listed with Mc Eng, Ae Eng, El Eng 329 and Cv Eng 318)

334 Theory of Stability I (Lect 3.0) Formulation of stability concepts associated with columns, beams and frames. Applications to some engineering problems utilizing numerical methods. Prerequisites: Bas En 110, Bas En 150 or E Mech 160, Math 204. (Co-listed with Mc Eng 334, Ae Eng 334)

336 Fracture Mechanics (Lect 3.0) Linear elastic and plastic mathematical models for stresses around cracks; concepts of stress intensity; strain energy release rates; correlation of models with experiment; determination of plane stress and plane strain parameters; application to design. Prerequisite: Bas En 110. (Co-listed with Ae Eng 336, Mc Eng 336)

337 Fatigue Analysis (Lect 3.0) The mechanism of fatigue, fatigue strength of metals, fracture mechanics, influence of stress conditions on fatigue strength, stress concentrations, surface treatment effects, corrosion fatigue and fretting corrosion, fatigue of joints, components and structures, design to prevent fatigue. Prerequisite: Bas En 110. (Co-listed with Mc Eng 338, Ae Eng 344)

341 Experimental Stress Analysis I (Lect 2.0 and Lab 1.0) Acquaints the student with some techniques of experimental stress analysis. Principal stresses, strain to stress conversion, mechanical and optical strain gages, electrical resistance strain gages, transducers, and brittle coatings. Prerequisite: Bas En 110. (Co-listed with Mc Eng 341, Ae Eng 341)

342 Experimental Stress Analysis II (Lect 2.0 and Lab 1.0) Acquaints the student with some techniques of experimental stress analysis. Topics include principal stresses, strain to stress conversion, transmission and reflection photo-elastic methods, Moire fringe methods and analogies. Prerequisites: Bas En 110 and E Mech 321. (Co-listed with Mc Eng 342, Ae Eng 342)

354 Variational Formulations of Mechanics Problems (Lect 3.0) Introduction and study of variational problems in classical dynamics and solid mechanics emphasizing the concepts of virtual work, minimum potential energy, and complementary energy. Variational inequalities. Prerequisites: Bas En 110, 150 or E Mech 160, Math 204. (Co-listed with Mc Eng 354)

361 Vibrations I (Lect 3.0) Equations of motion, free and forced vibration or single degree of freedom systems and multidegree of freedom systems. Natural frequencies, resonance, modes of vibration and energy dissipation are studies. The vibration of continuous systems is introduced. Prerequisites: Mc Eng 211 and Mc Eng 213, or Ae Eng 213 and Math 204. (Co-listed with Mc Eng 307, Ae Eng 307)

362 Experimental Vibration Analysis (Lect 2.0 and Lab 1.0) Methods for measuring and analyzing motion and strain response of dynamically excited structures. Includes frequency-response testing of elementary beam, torsion bar, plate and shell structures. Experiments on the effectiveness of isolators and dynamic absorbers. Prerequisite: E Mech 361 or Ae Eng 307 or Mc Eng 307. (Co-listed with Mc Eng 362, Ae Eng 362)

373 Advanced Dynamics (Lect 3.0) Review of kinematics of particles and rigid bodies. Development of equations of motion using energy principles and Euler's equations. Stability of motions. Spe-

cial topics. Prerequisites: Bas En 150 or E Mech 160, Math 204.

375 Structural Modal Analysis: Theory and Application (Lect 2.0 and Lab 1.0) A modeling technique for the dynamic behavior of structures. Topics include structural dynamics theory, digital signal processing and instrumentation, model parameter extraction, vibration simulation and design modification. Hands-on experience with an integrated analysis of the experimental model testing and the analytical finite element method. Prerequisite: Bas En 110 and 150 or E Mech 160, Math 203 and 204.

381 Introduction to Composite Materials & Structures (Lect 3.0) Introduction to fiber-reinforced composite materials and structures with emphasis on analysis and design. Composite micromechanics, lamination theory and failure criteria. Design procedures for structures made of composite materials. An overview of fabrication and experimental characterization. Prerequisite: Bas En 110. (Co-listed with Mc Eng 382 and Ae Eng 311)

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six (6) credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor. Consent of instructor required.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

406 Boundary Methods in Mechanics (Lect 3.0)Discussion of weighted residual methods and development of boundary integral and boundary element concepts with applications to problems in potential theory, elasticity, plate theory and plasticity with emphasis on solution of steady state and transient problems in potential theory and elasticity. Prerequisite: E Mech 307.

408 Finite Element Approximation II - Second Course (Lect 3.0) Continuation of Finite Element Approximation I-An Introduction; element selection and interpolation estimates, Lagrange, Hermite, and Isoparametric elements; mixed, hybrid, penalty and boundary elements; enginevalue and time-dependent problems; three-dimensional and nonlinear problems. Prerequisite: E Mech 307 or Mc Eng 312 or Ae Eng 352. (Colisted with Mc Eng 408, Ae Eng 408)

410 Seminar (Variable) Discussion of current topics. (Co-listed with Ae Eng 410 and Mc Eng 410)

412 Continuum Mechanics (Lect 3.0) Tensorial preliminaries, finite deformation and strain; general kinematics; stress; thermodynamic concepts; constitutive equations, elastic, fluid, plastic, and viscoelastic bodies. Introduction to microcontinuum concepts. Prerequisite: E Mech 311.

422 Theory of Elasticity (Lect 3.0) Formulation and study of standard boundary-value problems in linear elastostatics: uniqueness theorems, Saint-Venant's principle and complex-variable techniques of solution. Prerequisites: E Mech 322, Math 309, 351.

424 Engineering Plasticity II (Lect 3.0) Continued study of material strain-hardening and strain-rate effects; introduction to slip line fields and practical forming problems such as bending, drawing and extrusion; effects of ultra high pressure and combined stress states; pressure vessels. Prerequisite: E Mech 324.

427 Viscoelasticity (Lect 3.0) Constitutive equations for viscoelastic materials. Transform techniques. Thermal effects. Applications to special problems. Prerequisites: E Mech 311, Math 309, Math 351 or 357.

431 Theory of Plates (Lect 3.0) General coverage of various approaches to plate problems and the application of these methods to practical problems. Special topics include applications to elastic foundations, buckling and energy methods in plate theory. Prerequisite: Math 325. (Co-listed with Mc Eng 430)

432 Theory of Shells (Lect 3.0) General theory of stress analysis of shells based on topics in differential geometry and general elasticity theory. Theory is applicable to studies of the elastic behavior of flat plates and shells, buckling and post-buckling behavior of shells, and provides a basis for all shell theories which account for anisotropy, plasticity, creep, thermal strains, internal reinforcements, and transverse shearing deformations. Prerequisite: Math 325. (Co-listed with Mc Eng 432)

435 Theory of Stability II (Lect 3.0) Buckling of plates and shells, dynamic stability of elastic systems, nonconservative systems. Prerequisite: E Mech 334 or Mc Eng 334 or Ae Eng 334. (Co-listed with Mc Eng 424)

436 Advanced Fracture Mechanics (Lect 3.0) Mathematical theories of equilibrium cracks and brittle fracture; mathematical analysis of elastic-plastic fracture mechanics, COD, R-curve and J-integral analysis. Prerequisite: Ae Eng 336 or E Mech 336 or Mc Eng 336. (Co-listed with Mc Eng 436)

462 Theory of Vibrations II (Lect 3.0) Topics include: continuous systems, Fourier transform solutions, eigenvalue problems, random vibrations, nonlinear vibrations, and impact in continuous systems. Prerequisite: E Mech 361 or Mc Eng 307 or Ae Eng 307.

463 Theory of Random Vibrations (Lect 3.0) Statistical properties of random vibration processes including autocorrelation and covariance, spectral density of random excitation and response. Gaussian, narrow band and wideband processes. Response of multidegree of freedom systems to stationary random excitation. Prerequisite: E Mech 361 or Mc Eng and Ae Eng 307.

481 Wave Propagation in Continuous Media I (Lect 3.0) Linear wave equations. Wave motion in unbounded and bounded media. Effects of anisotropy. Elements of nonlinear one-dimension-

al wave propagation. Experimental techniques. Special topics. Prerequisite: E Mech 311.

482 Wave Propagation in Continuous Media II (Lect 3.0) Hyperbolic systems of equations, method of characteristics. Application of these techniques to mechanics; compressible fluids, elasticity, acceleration and shock waves. Nonlinear dispersive waves. Experimental techniques. Prerequisite: E Mech 481.

483 Mechanics of Composite Materials (Lect 3.0) Effective moduli of spherical, cylindrical and lamellar systems. Stress transfer in short fiber composites. Hygrothermomechanical constitutive relations. Interlaminar stress, strength and fracture of composite systems. Prerequisites: E Mech 381 or Mc Eng 382 or Ae Eng 311. (Co-listed with Mc Eng 485 and Ae Eng 485)

484 Analysis of Laminated Composite Structures (Lect 3.0) An overview of isotropic beams, plates and shells. Bending vibration, and buckling of composite beams and plates: exact and approximate solutions. Development of composite shell theory. Some simplified laminated shell solutions. Analysis of composite structures including transverse shear deformation effects. Prerequisite: E Mech 381 or Mc Eng 382 or Ae Eng 311. (Co-listed with Mc Eng 484 and Ae Eng 484)

487 Finite Element Approximation III - Nonlinear Problems (Lect 3.0) Formulation of nonlinear problems, iterative methods, solution of nonlinear problems, cover topics of interest to the class. Prerequisite: E Mech 408 or Mc Eng 408 or Ae Eng 408. (Co-listed with Mc Eng 487 and Ae Eng 487)

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

ENVIRONMENTAL ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

360 Environmental Law and Regulations (Lect 3.0) This course provides comprehensive coverage of environmental laws and regulations dealing with air, water, wastewater, and other media. The primary focus is permitting, reporting, and compliance protocols. The course topics include U.S. and international legal systems and judicial processes, liability, enforcement, Clean Air Act, Clean Water Act (NPDES) permitting), Safe Drinking Water Act, OSGA, TSCA, RCRA, and CERCLA. Case studies will be emphasized. (Co-listed with Cv Eng 360)

361 Remediation of Contaminated Groundwater and Soil (Lect 2.0 and Lab 1.0) Course covers current in-situ and ex-situ remediation technologies. Current literature and case studies are utilized to provide the focus for class discussions and projects. Prerequisites: Cv Eng 265, Ge Eng 337 or Graduate Standing. (Co-listed with Cv Eng 361)

362 Public Health Engineering (Lect 3.0) A comprehensive course dealing with the environmental aspects of public health. Prerequisites: Cv Eng 261 with grade of "C" or better. (Co-listed with Cv Eng 362)

363 Solid Waste Management (Lect 3.0) A systematic study of the sources, amounts and characteristics of solid wastes and methods used for their collection, reclamation, and ultimate disposal. Prerequisites: Cv Eng 261 with grade of "C" or better; or graduate standing. (Co-listed with Cv Eng 363)

365 Environmental Engineering Analysis Laboratory (Lect 1.0 and Lab 2.0) Environmental Engineering analytical principles and techniques applied to the quantitative measurement of water, wastewater and natural water environmental engineering. Prerequisites: Cv Eng 265 with grade of "C" or better; or graduate standing. (Co-listed with Cv Eng 365)

367 Introduction to Air Pollution (Lect 3.0) Introduction to the field of air pollution dealing with sources, effects, federal legislation, transport and dispersion and principles of engineering control. Prerequisite: Cv Eng 230 or equivalent; or graduate standing. (Co-listed with Cv Eng 367)

368 Air Pollution Control Methods (Lect 3.0) Study of the design principles and application of the state-of-the-art control techniques to gaseous and particulate emissions from fossil fuel combustion, industrial and transportation sources. Prerequisite: Cv Eng 230 or equivalent; or graduate standing. (Co-listed with Cv Eng 368)

369 Sanitary Engineering Design (Lect 2.0 and Lab 1.0) Functional design of water and waste water treatment facilities. Prerequisites: Cv Eng 265 with grade of "C" or better. (Co-listed with Cv Eng 369)

380 Water Resources and Wastewater Engineering (Lect 3.0) Application of engineering principles to the planning and design of multipurpose

projects involving water resources development and wastewater collection/treatment/disposal systems. Latest concepts in engineering analysis are applied to evaluation of alternative solutions. Prerequisites: Cv Eng 233, 235, 265. (Co-listed with Cv Eng 380)

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of the instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

410 Seminar (0.0 Hours) Discussion of current topics.

460 Chemical Principles in Environmental Engineering (Lect 3.0) The course develops fundamental chemical and physical principles underlying environmental engineering systems including drinking water, groundwater, and wastewater treatment; and natural environmental processes. Topics include adsorption, complex formation, acid-base equilibria, solubility, mass transfer and diffusion, electrochemistry, and chemical kinetics. Prerequisite: Graduate Standing. (Co-listed with Cv Eng 460)

461 Biological Principles in Environmental Engineering Systems (Lect 2.0 and Lab 1.0) Course covers the fundamental biological and biochemical principles involved in natural and engineered biological systems. (Co-listed with Cv Eng 461)

462 Physicochemical Operations in Environmental Engineering Systems (Lect 3.0) Course covers physicochemical operations and design in water, wastewater and aqueous hazardous waste treatment systems including coagulation, precipitation, sedimentation, filtration, gas transfer, chemical oxidation and disinfection, adsorption ion exchange. Prerequisite: Cv Eng 230 or equivalent. (Co-listed with Cv Eng 462)

463 Biological Operations in Environmental Engineering Systems (Lect 3.0) Course covers biological operations and design in water, wastewater and aqueous hazardous waste treatment systems including modeling of biological treatment processes; and design of activated sludge systems, trickling filters, rotating biological contractors, lagoons, nitrification and denitrification, and digestion process. Prerequisite: Cv Eng 230 or equivalent. (Co-listed with Cv Eng 463)

464 Industrial and Hazardous Waste Treatment (Lect 2.0 and Lab 1.0) Course covers fundamentals of industrial and hazardous wastewater treatment systems and characterization including physical, chemical and biological processes and laboratory pilot plant investigations. (Co-listed with Cv Eng 464)

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Consent of instructor.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

GEOLOGICAL ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

310 Seminar (Lect 0.5) Discussion of current topics. Prerequisite: Senior standing.

315 Statistical Methods in Environmental Geology and Engineering (Lect 3.0) Study of statistical methods applicable to geologic investigations in environmental protection studies. Topics include design of test programs to meet regulatory guidelines, statistical procedures for analysis of test data and applicable statistical techniques for comparing test conclusions with regulatory criteria.

331 Subsurface Hydrology (Lect 2.0 and Lab 1.0) Introduction to the theory and engineering concepts of the movement of subsurface fluids. Properties of water and other subsurface fluids. Hydraulic characteristics of earth materials. Engineering problems related to subsurface fluids. Prerequisite: Ge Eng 50.

333 Risk Assessment in Environmental Studies (Lect 3.0) This course will present the concepts required to assess the human health and environmental risks resulting from contaminants in soil and groundwater. Course topics include evaluation of data sets, exposure calculation, chemical fate and transport, and development of conceptual site models.

335 Environmental Geological Engineering (Lect 3.0) Introduction to engineering geologic mapping for site selection for solid waste disposal facilities; landfill site selection, design, permitting, construction, operation, and closeout/reclamation. Prerequisites: Ge Eng 275, accompanied or preceded by Cv Eng 215.

337 Geological Aspects of Hazardous Waste Management (Lect 3.0) Nature and classification of hazardous wastes; federal and state regulation for treatment and disposal; geological characterization of facility sites; design of impoundments, storage and containment facilities; ground water monitoring and protection; site permitting and licensing planning. Prerequisite: Ge Eng 275.

339 Groundwater Remediation (Lect 3.0) A survey of conventional and innovative techniques for remediation of contaminated groundwater. Topics include groundwater cleanup standards, physicochemical properties of groundwater and contaminants, fate and transport of contaminants

in the subsurface, hydrogeologic site characterization, and selection process of a remedial technology. Various computer programs developed to assist in preliminary selection and design of remediation technologies will be used. Prerequisite: Ge Eng 331.

340 Field Operations in Ground Water Hydrology (Lect 3.0) A survey of ground water field operations. Topics include ground water exploration, well drilling methods, drilling fluids, well screens, water and monitoring well design, well development and testing, and pumps. A design project will be completed. Prerequisite: Ge Eng 331.

341 Engineering Geology and Geotechnics (Lect 3.0) Study of procedures and techniques used to evaluate geologic factors for site selection and the design of engineered structures. Prerequisite: Ge Eng 275.

343 Subsurface Exploration (Lect 2.0 and Lab 1.0) Lectures and field and laboratory exercises in the use of geologic and geophysical techniques for evaluation of subsurface geology and resources. Prerequisites: Pe Eng 131, Geo 220.

344 Remote Sensing Technology (Lect 2.0 and Lab 1.0) Principles of digital image processing including image enhancement and multispectral classification. Emphasis upon design and implementation of remote sensing systems and analysis of remotely sensed data for geotechnical and environmental investigations. Prerequisite: Ge Eng 248.

346 Applications of Geographic Information Systems (Lect 2.0 and Lab 1.0) Applications of geographic information systems and remote sensing to environmental monitoring, mineral resource exploration and geotechnical site evaluation. Prerequisite: Ge Eng 275 or consent of instructor.

349 Computer Applications in Geological Engineering (Lect 3.0) Advanced topics in computer applications including: statistical analysis, geostatistical modeling, groundwater and contaminant transport simulation, computer contouring algorithms, and digital image processing. Emphasis is on understanding the mathematical algorithms and computer implementation as well as the practical application to site investigation, decision making, and modeling projects. Prerequisite: Ge Eng 249.

350 Geological Engineering Design (Lect 2.0 and Lab 1.0) Geological engineering design is an open-ended project course requiring the collection of data, analysis and synthesis of that data and design of a socially acceptable, economical solution to the selected problem. Oral and written reports are required. Prerequisite: To be taken in the semester before graduation.

351 Geological Engineering Case Histories(Lect 3.0) This course presents significant concepts in geological engineering practices by using examples from practical experience to illustrate the objectives. The examples will be drawn from classic case histories as well as the professional experience of the instructor.

353 Regional Geological Engineering Problems in North America (Lect 3.0) A physiographic approach to engineering materials and problems. Course emphasizes the distribution and engineering characteristics of soil and rock to construction and site problems and includes aggregates, foundations, excavations, surface and ground water, slope stability and arctic conditions.

371 Rock Engineering (Lect 3.0) Data requirements for design; engineering properties of rock; characterization of fractures and rock masses; stereonet analysis of discontinuities; graphic analysis of failure; ground stress distribution; tunnel construction methods; ground support principles; selection of tunneling equipment; and specifications for underground construction. Prerequisite: Ge Eng 275.

372 Soil Science in Engineering Practice Lect 3.0 A study of the ways in which soils and geologic conditions influence engineered projects. Soil formation, soil chemistry and properties to include composition, organic component, ion exchange and water relationships as well as erosion control and revegetation will be covered. Prerequisite: Ge Eng 275.

373 Geologic Field Methods (Lab 3.0) Field practice in geologic mapping and interpretaton in the Western United States using topographic base maps and aerial photos. Emphasizes the description and interpretation of stratigraphic sections, sedimentary and tectonic structures. Prerequisite: Two courses in either Geology or Geological Engineering.

374 Engineering Geologic Field Methods (Lab 3.0) Instruction in methods of field investigation required for engineering geological studies. Course will include procedures for interpretative mapping of surficial geologic conditions, site characterization, and evaluation of geologic hazards. Written reports are required. Prerequisite: Geo 373.

376 Mined-Land Reclamation (Lect 3.0) Permitting: the legal environment of reclamation and environmental impact assessment; post-mining land-use selection and mine planning for optimum reclamation of all mines: metal, non-metal, and coal; unit operations of reclamation; drainage, backfill, soil replacement, revegetation, maintenance, etc. Prerequisites: Ge Eng 50 and prerequisite or co-requisite; one of Ge Eng 246, Cv Eng 215, or Mi Eng 226. (Co-listed with Mi Eng 376)

381 Intermediate Subsurface Hydrology and Contaminant Transport Mechs (Lect 3.0) A study of the physical/chemical properties of rocks and sediments in the subsurface environment. Emphasis is put on waterrock properties such as permeability, capillarity, and mechanical dispersion. Both microscopic and macroscopic approaches are used. Prerequisites: Cv Eng 230 & Ge Eng 331.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six (6) credit hours allowed for gradu-

ation credit. Subject and credit to be arranged with the instructor.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

410 Seminar (Lect 1.0) Discussion of current topics. Prerequisite: Graduate student.

415 Advanced Geostatistics (Lect 3.0) Data estimation is an important aspect of minerals engineering. This advanced graduate level course studies the application of Geostatistics for data estimation. Such estimation results in unique spatial analyses. Students are encouraged to find spatial analyses of particular interest to each individual. Prerequisite: Ge Eng 315 or equivalent in probability and statistics course 200 level or higher.

431 Advanced Subsurface Hydrology (Lect 3.0) Advanced treatment of selected topics in subsurface hydrology, including groundwater contamination, contaminant transport, land disposal of wastes, aquifer test analysis, injection well technology, etc. Applied hydrogeologic site analysis and flow and transport modeling through solution of selected case examples. Prerequisite: Ge Eng 331 or equivalent.

432 Numerical Methods in Subsurface Flow (Lect 3.0) Development of governing balance equations, constitutive laws and mathematical models of groundwater flow and contaminant transport in porous media. Solution of mathematical models by finite difference and finite element methods for various boundary and initial conditions. Prerequisites: Ge Eng 331, Cmp Sc 73.

435 Advanced Concepts of Environmental Geological Engineering (Lect 3.0) Application of the principles of geology to the solution of engineering problems in environmental protection and remediation. Topics will include the study of geologic processes and the evaluation of geologic materials as they affect the potential for groundwater contamination, susceptibility of soils to erosion, characterization of the geologic environment for site stability and the analysis of the criteria necessary for selection of technologies for minimizing environmental impact. Prerequisite: Graduate level course in environmental geologic studies.

437 Advanced Geological & Geotechnical Design for Hazardous Waste Mgt (Lect 3.0) Geological and geotechnical design factors for hazardous waste management facilities and remedial actions (cleanup) of uncontrolled hazardous waste sites. Prerequisite: Ge Eng 337 or consent of instructor.

438 Remedial Engineering for Uncontrolled Hazardous Waste Sites (Lect 3.0) Discussion of remediation technologies for uncontrolled hazardous waste sites applicable to various conditions of site geology, hydrology, and waste characteristics. Discussion will emphasize case histories of previous remediation actions and the design of alternate remediation technologies for an uncontrolled hazardous waste site. Prerequisite: Ge Eng 338.

441 Engineering Geology and Geotechnics II (Lect 3.0) Advanced level lecture topics in the analysis of geologic factors for the solution of engineering problems. Specific emphasis is placed on state-of-the-art concepts and procedures of investigation for geologic studies. Prerequisite: Ge Eng 341.

446 Advanced Remote Sensing and Image Processing (Lect 2.0 and Lab 1.0) Quantitative methods of utilizing remote sensing technology for terrain analysis. Digital image processing of landsat and/or aircraft scanner data for mineral resource studies and geological engineering applications. Prerequisite: Ge Eng 246.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

491 Internship (Variable) Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

GEOLOGY

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

305 Hydrogeology (Lect 3.0) This course discusses geologic aspects of major surface and subsurface hydrologic systems of North America. Chemical and physical relationships between groundwater and fractures, faults, karst, subsurface pressures, mineral deposits plus both contaminant and hy-

drocarbon migration are discussed. Prerequisites: Ge Eng 50 or Geo 51, Geo 223 recommended.

312 Ore Microscopy (Lect 1.0 and Lab 2.0) A study of polished sections of minerals and ores under reflected light. Includes the preparation of polished sections, the identification of ore minerals, and the study of the textures, associations, and alterations of ore minerals. Prerequisite: Geo 113.

324 Advanced Stratigraphy and Basin Evolution (Lect 3.0) Advanced topics in sedimentary geology including: tectonic controls on sedimentary basin development, global sequence stratigraphy, regional facies and diagenetic patterns, basin hydrogeology, thermal evolution of basins and distribution of economic resources. Prerequisites: Geo 223, 220, preceded or accompanied by Geo 275 recommended.

325 Advanced Physical Geology (Lect 3.0) History and materials of the Earth's crust, structures and geological features of the surface. Study of common minerals and rocks, topographic and geologic maps, depositional systems, sedimentary classification systems. Prerequisite: Consent of instructor.

329 Micropaleontology (Lect 2.0 and Lab 1.0) Introduction to the preparation and study of microscopic fossils. Prerequisite: Geo 227.

332 Depositional Systems (Lect 3.0) Depositional systems and their interpretation using seismic stratigraphy. Emphasis on deltaic formations, submarine fans, carbonate depositional environments and their recognition using reflection seismic techniques. Field trip fee required. Prerequisite: Geo 223.

338 Computer Mapping in Geology (Lect 1.0 and Lab 1.0) This course teaches the basics of computer gridding, contouring, digitization, volumetrics and generation of three dimensional diagrams both on the personal computer and on the UMR mainframe. Strengths and weaknesses of various software packages, including gridding algorithms and editing packages, are compared. Prerequisites: Cmp Sc 73, Geo 51.

340 Petroleum Geology (Lect 2.0 and Lab 1.0) Principles of origin, migration, and accumulation of oil and gas. The laboratory introduces the procedures used for exploration, and development of hydrocarbon resources. Prerequisite: Geo 220.

341 Applied Petroleum Geology (Lect 1.0 and Lab 2.0) The principles of petroleum geology are applied in solving hydrocarbon exploration and developmental problems. Geological and economical techniques for evaluating hydrocarbonbearing reservoirs are presented, with methods for decisionmaking under conditions of extreme uncertainty. Prerequisite: Geo 340.

345 Radioactive Waste Management and Remediation (Lect 3.0) Sources and classes of radioactive waste, long-term decay, spent fuel storage, transport, disposal options, regulatory control, materials issues, site selection and geologic characterization, containment, design and monitoring requirements, domestic and foreign waste disposal programs, economic and environmental issues; history of disposal actions, and conduct of remedial actions and cleanup. Prerequisite: Math 204. (Co-listed with Nu Eng 345)

373 Field Geology (Lab 3.0) Field practice in geologic mapping and interpretation in the Western United States using topographic base maps and aerial photos. Emphasizes the description and interpretation of stratigraphic sections, sedimentary and tectonic structures. Prerequisite: Two Geology courses.

374 Advanced Field Geology (Lab 3.0) Detailed field work in areas related to the projects of Geology 373. Courses to be taken the same summer. A written report on the full summer's projects is required. Prerequisite: Geo 373.

375 Applied Geochemistry (Lect 2.0 and Lab 1.0) Application of the principles and techniques of geochemistry to mineral exploration. Prerequisites: Geo 275 and Geo 113.

376 Aqueous Geochemistry (Lect 3.0) Studies of the interaction of water with minerals and organic materials at low temperatures; including processes affecting the migration of elements (alteration, precipitation, and adsorption), the influence of geochemical processes on water composition, weathering, soil formation, and pollution. Prerequisite: Geo 275.

383 Electrical Methods in Geophysics (Lect 3.0) The theory and instrumentation for measurements of the electrical properties of the earth. Includes passive and active techniques, the advantages and disadvantages of the various techniques, and geologic interpretations of electrical soundings. Several weekends are spent making a variety of electrical surveys of local features. Prerequisites: Math 325 and Geop 321.

384 Gravity and Magnetic Methods (Lect 3.0) The theory of gravity and magnetic surveying for geologic bodies of economic interest. Includes methods for the calculation of size and depth of bodies with different degrees of magnetization and density. Prerequisites: Math 325 and Geop 321.

385 Exploration and Development Seismology (Lect 2.0 and Lab 1.0) Principles of reflection seismology as applied to the delineation of geologic structures and the determination of stratigraphy and lithology. Emphasis on both the capabilities and limitations of the seismic method. The laboratory utilizes both modeled and actual seismic data. Prerequisites: Geo 220, Geo 223 or permission of instructor.

386 Wave Propagation (Lect 3.0) A study of Hamilton's principle and energy theorems, fundamentals of plane wave theory, waves in stratified fluids, elastic waves in solids, electromagnetic and hydromagnetic radiation, and Allens's functions and point sources. Prerequisites: Geop 286 and 321.

387 Acquisition of Seismic Data (Lect 2.0 and Lab 1.0) Theory and application of the acquisition of seismic data. Determination of recording and en-

ergy source array responses, evaluation of energy sources, and the design of a complete acquisition system. Prerequisite: Geop 286 and 380 or permission of instructor.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six (6) credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

394 Coal Petrology (Lect 3.0) Formation, composition, and properties of coals. Discussion of the geology of selected coal deposits, the analysis of coal, and the optical identification of coal minerals. Prerequisite: Permission of instructor.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

410 Seminar (Variable) Discussion of current topics.

411 Advanced Mineralogy (Lect 2.0 and Lab 1.0) A study of selected mineralogy topics. Emphasis will vary with class interest. Current topics include crystallography, composition of ashflow tuffs, and mineralogy of wall-rock alteration.

412 Advanced Ore Microscopy (Lect 1.0 and Lab 2.0) A study of ore suites utilizing various advanced, quantitative ore microscopy techniques including hardness, spectral reflectance, indentation, color, rotation property measurements, fluid inclusion geothermometry, and salinity measurements. Laboratory study includes demonstration and operation of the luminoscope and other microbeam techniques. Prerequisite: Geo 312.

413 Clay Mineralogy (Lect 2.0 and Lab 1.0) Mineral structure, geochemical properties, occurrence, environment, and uses of clays. Determination of physical properties, optics, x-ray diffraction, and thermal features of clays. Field trip fee required. Prerequisites: Geo 113 and 275, or Chem 237, or Cv Eng 315, or Ge Eng 372.

423 Sedimentary Basin Analysis (Lect 3.0) An advanced study of stratigraphic, diagenetic and tectonic processes in sedimentary basins. Prerequisites: Geo 220, 223, 275 or 375 or 376.

430 Advanced Petrology of the Metamorphic Rocks (Lect 2.0 and Lab 1.0) Survey of metamorphic processes and the interpretation of metamorphism from field and laboratory studies. Discussion of recent ideas and techniques in the study of metamorphic rocks. Prerequisite: Geo 234.

431 Clastic Sedimentary Petrology (Lect 2.0 and Lab 1.0) Petrology and petrography of clastic sedimentary rocks. Emphasis on origin, diagnosis and description of clastic, sedimentary rocks. Prerequisite: Geo 223.

432 Carbonate Petrology (Lect 2.0 and Lab 1.0) Petrology, chemistry and sedimentology of carbonates and other associated chemical sedimentary rocks. Prerequisites: Geo 130, 114, 223 and Chem 3 or equivalent Geo 275 recommended.

433 Advanced Igneous Petrology (Lect 2.0 and Lab 1.0) The genesis of eruptive rocks as evidenced by the physicalchemical conditions of formation of their constituent minerals. A critical examination of various magmatic processes. Use of advanced petrographic techniques. Prerequisite: Geo 234.

435 Applied Ore Microscopy (Lect 1.0 and Lab 2.0) Application of ore microscopic and petrographic techniques to problems in ore beneficiation, pelleting, sintering, smelting, refining, refractories, cement, mining, and exploration. Discussions and laboratories are based upon industrial case histories. Prerequisite: Geo 312.

437 Advanced Palynology (Lect 1.0 and Lab 2.0) Study of the processes of sporopollenin preservation, sedimentation and palynofacies. Major emphasis on independent palynostratigraphic research. Chronicle of Phaneozoic palynology in lectures. Prerequisite: Geo 223 or Geo 329.

440 Geochemistry (Lect 3.0) A study of the absolute and relative abundance of the elements and isotopes in the earth, and the principles of migration and concentration in the formation of soils, rocks and mineral deposites. Prerequisites: Chem 243 and Geo 234.

443 Advanced Petroleum Geology (Lect 1.0 and Lab 2.0) Examples of various types of oil and gas accumulation are reviewed in detail. Study of criteria useful in evaluating the petroleum potential of undrilled areas. Special investigation assignment is required. Prerequisite: Geo 340.

475 Mining Geology (Lect 2.0 and Lab 1.0) Application of geology, geochemistry, and geophysics in exploration for exposed and hidden mineral deposits. Geologic mapping, sampling, geochemical, geophysical, laboratory investigations, tonnage and grade calculations, data compilation, evaluation and report preparation and related topics are discussed. Prerequisites: Geo 220, 292.

476 Regional Mineral Exploration Emphasing Gold (Lect 1.0 and Lab 2.0) Exploration for gold in the precambrian shield and cordilleras of North America. Development of exploration models of gold deposits. Evaluation of mineral potential by geological, geophysical and geochemical methods. Economics of gold exploration and mine development. Prerequisites: Geo 220, 275, 294.

480 Geotectonics (Lect 3.0) A critical study of the origin, and differentiation of the earth, evolution of the crust, and plate tectonics. Geology of the continents and ocean basins. Regional tectonic analysis of precambrian shields, platforms, orogenic belts, and a review of internal energy sources. Emphasis is on North America. Prerequisite: Geo 220.

481 Geodynamics (Lect 3.0) The applications of continuum physics to geological problems. Topics include plate tectonics, stress and strain in solids, elasticity and flexure, heat transfer, gravity, fluid

mechanics, rock rheology, faulting, and flow in porous media. Prerequisites: Math 22 and Geo 220.

489 Ore Deposition (Lect 2.0 and Lab 1.0) An advanced study of mineral deposits, time and space in deposition, theories of deposition and their effect on exploration. Discussions based on maps, logs, and samples from the world's typical mineral deposits. Two all day field trips at student expense required. Prerequisite: Geo 294.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

GEOPHYSICS

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

321 Potential Field Theory (Lect 3.0) The mathematics and physics of gravitational, magnetic, and electrical fields of the earth as derived from potential functions, with applications to practical problems. The theorems of Laplace, Poisson, Gauss, and Green and their applications to geophysics are presented. Prerequisite: Accompanied or preceded by Math 325.

336 Geophysical Field Methods (Lect 2.0 and Lab 1.0) Imaging of selected subsurface and engineering features by various geophysical methods. Special emphasis on ground penetrating radar and magnetic methods; and the acquisition and reduction of associated data. One field trip at student expense required. Prerequisite: Geop 384 or permission of instructor.

380 Seismic Stratigraphy (Lect 2.0 and Lab 1.0) A study of the seismic expression of depositional models. Reflection patterns and reflection amplitudes are interpreted to determine bed thicknesses, fluid content, depositional environment, and lithology. Special data acquisition and processing techniques are examined. Prerequisites: Geop 385, Geo 220, 223.

381 Global Tectonics (Lect 3.0) An integrated view of the Earth's structure and dynamics with an emphasis on information gained through geophysical methods. Topics include seismology, heat flow, gravity, rheological and compositional structure, plate motions and intermotions, and mantle driving mechanisms for plate tectonics. Prerequisites: Physics 23 and 24, Geo 220.

382 Environmental and Engineering Geophysics (Lect 2.0 and Lab 1.0) An introduction to the theory and application of the gravity, magnetic, resistivity, self-potential, induced polarization and electromagnetic methods as applied to the solution of engineering and environmental problems. Prerequisite: Math 22.

383 Electrical Methods in Geophysics (Lect 1.0 and Lab 2.0) The theory and instrumentation for measurements of the electrical properties of the earth. Includes passive and active techniques, the advantages and disadvantages of the various techniques, and geologic interpretations of electrical soundings. Several weekends are spent making a variety of electrical surveys of local features. Prerequisites: Math 325 and Geop 285 or Geop 382.

385 Exploration and Development Seismology (Lect 2.0 and Lab 1.0) Principles of reflection seismology as applied to the delineation of geologic structures and the determination of stratigraphy and lithology. Emphasis on both the capabilities and limitations of the seismic method. The laboratory utilizes both modeled and actual seismic data. Prerequisite: Math 22.

386 Wave Propagation (Lect 3.0) A study of Hamilton's principle and energy theorems, fundamentals of plane wave theory, waves in stratified fluids, elastic waves in solids, electromagnetic and hydromagnetic radiation, and Allen's functions and point sources. Prerequisites: Geop 281, 321.

387 Acquisition of Seismic Data (Lect 2.0 and Lab 1.0) Theory and application of the acquisition of seismic data. Determination of recording and energy source array responses, evaluation of energy sources, and the design of a complete acquisition system. Prerequisites: Geop 286, 380.

388 Geophysical Instrumentation (Lab 1.0) Field and laboratory practice in the use of geophysical instrumentation. Techniques of geophysical data reduction and interpretation are also covered. May be taken more than once for credit with Geop 383 and Geop 384. Prerequisite: Concurrent registration in Geop 382, 283 or 384.

389 Seismic Data Processing (Lect 2.0 and Lab 1.0) Introduction to seismic data processing. Topics to be covered include statics corrections, filtering, velocity analysis, deconvolution, stacking and migration. Prerequisites: Math 22 and Geop 286 or Geop 385.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to en-

gage in research. Not for graduate credit. Not more than six credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

410 Seminar (Variable) Discussion of current topics.

485 Advanced Seismic Data Processing (Lect 2.0 and Lab 1.0) Theory and application of seismic data processing. Topics to be covered include convolution, correlation, deconvolution, 2-D filtering, migration and inversion. Prerequisites: Geop 385, 389, Stat 215.

486 The Theory of Elastic Waves (Lect 2.0 and Lab 1.0) A mathematical study of elastic waves in the layered earth. Prerequisite: Geop 386.

487 Geophysical Inverse Theory (Lect 3.0) A study of inverse theory applied to geophysical data, focusing on the relationship between data and model spaces and ways to estimate model parameters via global and local optimization techniques. Prerequisites: Geop 286 or 384, Math 325, Stat 215.

488 Seismic Interpretation (Lect 1.0 and Lab 2.0) The integration of geologic information, well log data and seismic information for interpreting the earth's subsurface. The role of data acquisition and processing is emphasized. Laboratory exercises provide experience with both real and modeled data. Prerequisite: Geop 380, 385.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

MATHEMATICS

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

302 Intermediate Differential Equations (Lect 3.0) Linear differential equations, vector-matrix systems, existence and uniqueness theory, nonlinear systems, phase-plane analysis, introduction to stability theory. Prerequisite: Math 204 or Math 229.

303 Mathematical Modeling (Lect 3.0) Model construction and the modeling process, model fitting, models requiring optimization, empirical model construction, modeling dynamic behavior. Individual and team projects. Prerequisites: Math 204 or 229, programming competency.

305 Modern Algebra I (Lect 3.0) The abstract concepts of a group and a ring are introduced. Permutation groups, subgroups, homomorphisms, ideals, ring homomorphisms and polynomial rings are studied. Prerequisite: Math 209.

306 Modern Algebra II (Lect 3.0) This course is a continuation of Math 305. Rings and fields are discussed. Euclidean domains, principal ideal domains, unique factorization domains, vector spaces, finite fields and field extensions are studied. Prerequisite: Math 305.

307 Combinatorics and Graph Theory (Lect 3.0) Covers some basics of enumeration and graph theory. Topics are selected from the following: permutations combinations, the inclusion/exclusion principle, generating functions, recurrence relations, trees, networks, graph connectivity and graph coloring. Prerequisite: Cmp Sc 158 or Math 209.

308 Linear Algebra II (Lect 3.0) Eigenvalue problems, Cayley-Hamilton theorem, Jordan normal form, linear functionals, bilinear forms, quadratic forms, orthogonal and unitary transformations, selected applications of linear algebra. Prerequisite: Math 208.

309 Advanced Calculus I (Lect 3.0) Completeness of the set of real numbers, sequences and series of real numbers, limits, continuity and differentiability, uniform convergence, Taylor series, Heine-Borel theorem, Riemann integral, fundamental theorem of calculus, Cauchy-Riemann integral. Prerequisite: Math 209 or a 300-level mathematics course or graduate standing.

311 Advanced Calculus II (Lect 3.0) Euclidean n-space, differentiation and integration of scalar functions of several variables, maxima and minima theory, change of variables, differentiation and integration of vector functions of several variables, Divergence theorem, Stokes' theorem. Prerequisite: Math 309.

312 Introduction to Differential Geometry (Lect 3.0) Elements of the geometry of curves and surfaces in Euclidean three-space using methods of advanced calculus and vectors. Prerequisite: Math 309 or Math 322.

315 Introduction to Real Analysis (Lect 3.0) Riemann-Stieltjes integration, sequences and series of functions, uniform approximation, the Banach

Space C(a,b), Lebesgue measure and integration, the space LP(a,b), Fourier series. Prerequisite: Math 309.

322 Vector and Tensor Analysis (Lect 3.0) Vector algebra, vector differential and integral calculus, line and surface integrals, theorems of Stokes and Gauss, tensor algebra and tensor analysis, applications to problems in kinematics, elasticity theory, fluid mechanics, electromagnetic theory, relativity theory. Prerequisite: Math 22.

325 Partial Differential Equations (Lect 3.0) Linear equations, heat equation, eigenfunction expansions, Green's formula, inhomogeneous problems, Fourier series, wave equation. Prerequisite: Math 204.

330 Topics in Geometry (Lect 3.0) A survey of non-Euclidean geometries, finite geometries, affine and projective planes, metric postulates for the Euclidean plane, and selected topics. Prerequisite: Math 208.

351 Introduction to Complex Variables (Lect 3.0) The basic tools of complex variables are studied. These include the Cauchy-Riemann equations, complex contour integration, the Cauchy-Goursat theorem, conformal mappings, the calculus of residues and applications to boundary value problems. Prerequisite: Math 204.

357 Engineering Mathematics I (Lect 3.0) Topics in vector analysis, matrices, and determinants, Laplace transform, complex variables. Prerequisite: Math 204.

358 Engineering Mathematics II (Lect 3.0) Infinite series, Fourier series, partial differential equations. Boundary value problems, the Fourier Integral, Bessel and Legendre functions. Prerequisite: Math 204.

361 Problem Solving in Pure Mathematics (Lect 1.0) Problems from pure mathematics, including analysis, algebra, number theory, set-theory, finite mathematics, probability and statistics. Emphasis on identifying or inventing ways to solve problems based on the student's entire mathematics background. Prerequisites: Corequisite Math 309 and Senior standing.

371 Problem Solving in Applied Mathematics (Lect 1.0) Problems from applied mathematics which are open-ended, and do not always have a unique correct solution. Emphasis on developing mathematical models and writing solution narratives, including clarity, analysis, and design. Prerequisites: Math 209 and Senior standing.

381 Great Theorems in Mathematics (Lect 1.0) A study of some of the great theorems which have shaped the development of mathematics and human civilization. History, the changing nature of mathematics, and the mathematical content of the theorems themselves, will all be addressed. Sources as close to the originals as possible will be used. Prerequisites: Math 209 and Senior standing.

383 Operational Calculus (Lect 3.0) The Laplace transformation, properties of the transformation, various applications to ordinary and partial differential equations, systems with step and Dirac functions as driving forces, various non-elementary functions and their transforms, problems in heat conduction and wave motion, Fourier transforms and their operational properties. Prerequisite: Math 204.

385 Introduction to Topology (Lect 3.0) Metric spaces; general topological spaces; connectedness, compactness, separation properties, functions and continuity. Prerequisite: Math 309.

390 Undergraduate Research (Variable) This course is designed for the undergraduate student who wishes to engage in research. It is not to be used for graduate credit nor for more than six credit hours of undergraduate credit. The subject and credit are to be arranged with the instructor. Prerequisite: Consent of instructor.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

402 Mathematical Physics I (Lect 3.0) Vector spaces, generalized coordinate transformations, vector analysis, tensors, partial differential equations in physics and boundary value problems, orthogonal functions and solutions to ordinary differential equations, hypergeometric, confluent hypergeometric, Legendre, Laguerre, and Bessel functions, Hermite polynomials, Green's functions in one dimension.

403 Mathematical Physics II (Lect 3.0) Green's functions in three dimensions, integral equations, complex variable theory and contour integration, group theory with applications to quantum mechanics, solid state and molecular physics. Prerequisite: Math 402 or equivalent.

406 Theory of Rings (Lect 3.0) Rings, homomorphisms and ideals, quotient rings, modules and radicals. Additional selected topics such as polynomial rings, Boolean rings, Noetherian rings, matrix rings, simple rings, function rings, and nonassociative algebras. Prerequisite: Math 306.

407 Group Theory (Lect 3.0) Groups, subgroups, and factor groups; homomorphisms, isomorphisms, and associated theorems; abelian groups; Sylow theorems and p-groups; permutation groups; free groups and generators; representation theory; cohomology theory. Prerequisite: Math 306.

408 Applied Matrix Theory (Lect 3.0) A second course in matrix theory directed toward applications. Linear spaces, linear operators, equivalence and similarity, spectral theorem, canonical forms, congruence, inertia theorem, quadratic forms, singular value decomposition and other factorizations, generalized inverses. Applications to optimization, differential equations, stability. Prerequisites: Math 203, 208, or 302.

410 Graduate Seminar (Variable) Discussion of topics of current interest. Prerequisite: Graduate standing.

415 Functions of a Real Variable I (Lect 3.0) Measure spaces, extensions of measures, probability spaces, measures and distributions in normed linear spaces, product measures, independence, integral and expectation, convergence theorems, Radon-Nikodyn theorem and applications. Lp spaces, selected topics. Prerequisite: Math 315.

416 Functions of a Real Variable II (Lect 3.0) Abstract measures and integrals, the Daniell integration theory, integration on locally compact Hausdorff spaces, integration in function spaces, selected topics. Prerequisite: Must be preceded by Math 415.

417 Functional Analysis I (Lect 3.0) Linear transformations, Hahn-Banach theorem, open-mapping theorem, closed graph theorem, uniform boundedness theorem, self adjoint and normal operators, and related topics of Banach and Hilbert space theory. Prerequisites: Math 308 and Math 385.

418 Functional Analysis II (Lect 3.0) Spectral analysis of linear operators, spectral theorems, selected applications, an introduction to the theory of topological linear spaces, and papers from the recent literature. Prerequisites: Math 415 and 417.

425 Hilbert Space Structures and Methods for Application (Lect 3.0) Foundations of the abstract theory of linear operators in Hilbert spaces, Banach spaces, and topological linear spaces. Application of abstract theory in constructing computational techniques (method of Rayleigh-Ritz) in eigenvalue problems associated with linear differential and integral equations arising in physical applications. Introduction to theory of distributions and Green's functions. Prerequisite: Math 308.

426 Green's Function Structures and Methods for Application (Lect 3.0) Continuation of Math 425. Theory of distributions (Dirac Delta function) and Green's functions. Applications in the solution of boundary value problems for linear partial differential equations arising in physical applications. Integral equations in several independent variables. Method of characteristics in solving partial differential equations. Prerequisite: Math 425.

430 Theory of Differential Equations I (Lect 3.0) Stability theory, Liapunov's direct method, periodic solutions, Poincare-Bendixson theory, applications. Prerequisite: Math 302.

431 Theory of Differential Equations II (Lect 3.0) Continuation of Math 430. Nonlinear oscillations, solutions near singular points, asymptotic methods, differential equations on manifolds, boundary-value problems. Prerequisite: Math 302.

435 Calculus of Variations I (Lect 3.0) Linear spaces, linear operators, and functionals, necessary conditions, transversality, corner conditions, Hamilton Jacobi theory, direct methods, eigenvalue problems, isoperimetric problems, theory of the second variation, differential forms and n-dimensional manifolds, applications to differential equations, conservation laws, dynamic programming, and Pontryagin maximum principle, application in physics, engineering economics. Prerequisite: Math 311.

436 Calculus of Variations II (Lect 3.0) Continuation of Math 435. Prerequisite: Must be preceded by Math 435.

451 Functions of a Complex Variable I (Lect 3.0) Complex plane, complex function theory, elementary Riemann surfaces, conformal mapping, complex integration, infinite complex series and sequences, calculus of residues with applications. Prerequisite: Math 311.

452 Functions of a Complex Variable II (Lect 3.0) Argument principle and consequences; harmonic functions and Dirichlet's problem; infinite products; entire, meromorphic and rational functions; analytic continuation; symmetry principle; conformal mapping; functions of several complex variables. Prerequisite: Preceded by Math 451.

461 Introduction to Abstract Harmonic Analysis I (Lect 3.0) Topological groups, linear spaces, group representation theory, permutation groups, rotation groups, Lorentz groups, Haar integral, Banach algebras, C*-algebra, examples in physics. Prerequisites: Math 305 and 385.

462 Introduction to Abstract Harmonic Analysis II (Lect 3.0) Continuation of Math 461. Prerequisite: Must be preceded by Math 461.

465 Mathematical Programming (Lect 3.0) Techniques for modeling decision-making problems using appropriate mathematical models of linear, integer, combinatorial, or nonlinear programming. Modeling techniques will be illustrated with examples. A comprehensive treatment of applicable algorithms to solve wide varieties of mathematical programming models will be provided. Prerequisites: Stat 213 or equivalent and (Eng Mg 382 or Math 203 or Math 208). (Co-listed with: Eng Mg 465)

475 Theory of Partial Differential Equations (Lect 3.0) Classical wave, potential, and heat equations; classification into elliptic, parabolic, and hyperbolic types; existence and uniqueness proofs. Prerequisite: Math 309.

483 Special Functions (Lect 3.0) Infinite products, gamma and beta functions, asymptotic series, the hypergeometric function, generalized hyper-geometric functions, Bessel functions, generating functions; polynomials of legendre, Hermite, Laguerre, and Jacobi; elliptic functions, theta functions, Jacobian elliptic functions. Prerequisites: Math 309 and 351.

485 Topology I (Lect 3.0) Topological spaces, uniform and quasi-uniform spaces, product and quotient spaces, separation properties and connected spaces, compactness. Prerequisite: Math 385.

486 Topology II (Lect 3.0) Metrizability conditions, the theory of convergence using both filters and nets, completions and compactifications, and papers from the recent literature. Prerequisite: Math 485.

487 Rings of Real, Continuous Functions I (Lect 3.0) Rings of real, continuous functions on topological spaces, ideals and z-filters, completely regular spaces, ordered residue class rings,

Stone-Cech compactification. Prerequisites: Math 305 and Math 385.

488 Rings of Real, Continuous Functions II (Lect 3.0) Continuation of Math 487. Real compact spaces, homomorphisms and continuous mappings, hyper-real fields, prime ideals, topics from current research. Prerequisite: Math 487.

490 Research (Variable) Investigation of an advanced nature leading to the preparation of a thesis or dissertation.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

MECHANICAL ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

302 Synthesis of Mechanisms (Lect 3.0) Synthesis of planar mechanisms for function generation, path generation, and motion generation. Emphasis is on analytical methods for synthesis. Prerequisite: Mc Eng 213.

304 Compliant Mechanism Design (Lect 3.0) Introduction to compliant mechanisms; review of rigid-body mechanism analysis and synthesis methods; synthesis of planar mechanisms with force/energy constraints using graphical and analytical methods; pseudo-rigid-body models; force-deflection relationships; compliant mechanism synthesis methods; and special topics, e.g. bistable mechanisms, constant-force mechanisms, parallel mechanisms, and chain algorithm in design. Emphasis will be on applying the assimilated knowledge through a project on compliant mechanisms design. Prerequisites: Mc Eng 213, Bas En 110.

305 Lubrication (Lect 3.0) Development of basic principles of bearing analysis including manufacture and properties of lubricants, hydrodynamics and hydrostatic lubrication, journal and thrust bearings, ball and roller bearings, boundary considerations, and bearing materials. Prerequisite: Mc Eng 231.

306 Material Processing by High-Pressure Water Jet (Lect 3.0) Methods of generating high pressure water jets; standard equipment, existing techniques, and basic calculations. Application of water jets to materials cutting and mineral processing. Safety rules. The course will be supported by laboratory demonstrations. Prerequisite: Mc Eng 231 or undergraduate fluids course. (Co-listed with Mi Eng 306)

307 Vibrations I (Lect 3.0) Equations of motion, free and forced vibration of single degree of freedom systems and multidegree of freedom systems. Natural frequencies, resonance, modes of vibration and energy dissipation are studies. The vibration of continuous systems is introduced. Prerequisites: Mc Eng 211 and 213, or Ae Eng 213 and Math 204. (Co-listed with E Mech 361, Ae Eng 307)

308 Rapid Product Design and Optimization (Lect 3.0) Product Life cycle design; Finding design solutions using optimization technique; Rapid product realization using rapid prototyping and virtual prototyping techniques. Prerequisite: Mc Eng 208.

309 Engineering Acoustics I (Lect 3.0) Introduction to acoustical theory and measurement with emphasis on mechanical and aerospace engineering applications. Plane and spherical wave propagation, resonators and filters, absorption, room acoustics, human response to noise, noise legislation, noise control. Use of common instrumentation in several projects. Prerequisites: Mc Eng 211 and 213, or Ae Eng 213 and Math 204. (Co-listed with Ae Eng 309)

311 Introduction to Continuum Mechanics (Lect 3.0) Introductory cartesian tensor analysis to aid in the development of the theory of a continuum. Kinematics of deformation, stress tensor, equations of motion, equations of mass and energy balance. Examples from specific material theories in solid and fluid mechanics. Prerequisites: Bas En 110, Math 204. (Co-listed with E Mech 311)

312 Finite Element Approximation I—An Introduction (Lect 3.0) Variational statement of a problem. Galerkin Approximation, finite element basis functions and calculations, element assembly, solution of equations, boundary conditions, interpretation of the approximation solution, development of a finite element program, two-dimensional problems. Prerequisite: Math 204. (Co-listed with E Mech 307, Ae Eng 352)

313 Intermediate Dynamics of Mechanical and Aerospace Systems (Lect 3.0) Principles of dynamics are applied to problems in the design of mechanical and aerospace systems; basic concepts in kinematics and dynamics; dynamics of systems of particles; dynamics of rigid bodies, three-dimensional effects in machine elements; dynamic stability, theory and applications; methods of analytical dynamics. Prerequisite: Mc Eng 213 or Ae Eng 213. (Co-listed with Ae Eng 313)

314 Applications of Numerical Methods to Mechanics Problems (Lect 3.0) Numerical solutions of statics, vibrations, and stability problems. Direct stiffness formulations are developed and user-oriented computer codes are used to solve practical structures problems. Computer graphics techniques are utilized to prepare data and display results. Prerequisites: Bas En 110 and either Bas En 150 or E Mech 160. (Co-listed with E Mech 305)

315 Concurrent Engineering I (Lect 3.0) Students will be introduced to the concurrent engineering approach to product development. They will learn to set up quantitative requirements and then use a quantitative rating process to identify the critical requirements relating to the desired product. The interaction between design, manufacturing, assembly, cost, and supportability will be covered. The students will form teams and practice the concurrent engineering process for simple products. Prerequisites: Mc Eng 213 or Ae Eng 231, and Bas En 110. (Co-listed with Ae Eng 315)

316 Concurrent Engineering II (Lab 3.0) Students will form groups and then using the electronic data based approach apply the concurrent engineering process to develop products. Areas to be covered are the customer, design, manufacturing, assembly, cost and supportability. Prerequisite: Ae Eng 315 or Mc Eng 315. (Co-listed with Ae Eng 316)

319 Advanced Thermodynamics (Lect 3.0) After a short review of classical thermodynamics, the elements of chemical reactions, chemical equilibrium, statistical thermodynamics, and the basic concepts of kinetic theory are presented. Prerequisite: Mc Eng 221. (Co-listed with Ae Eng 319)

322 Introduction to Solid Mechanics (Lect 3.0) Review of basic concepts in continuum mechanics. Finite elasticity: some universal solutions for isotropic materials, application of special mechanical models. Linear elasticity: compatibility, stress functions, superposition, special examples such as extension, torsion, bending, and plane problems. Elements of plasticity. Prerequisite: E Mech 311. (Co-listed with Ae Eng 322, E Mech 322)

323 Transport Phenomena in Manufacturing Processes (Lect 3.0) A study of the important role that transport phenomena (heat and mass transfer and fluid flow) play during various manufacturing processes including metal casting, joining and welding extrusion, forging, crystal growth, chemical deposition, and thermal spray deposition. Prerequisites: Mc Eng 225 and 231.

325 Intermediate Heat Transfer (Lect 3.0) Analytical study of conduction; theory of thermal radiation and applications; energy and momentum equations in convective heat transfer and review of empirical relations. Current topics are included. Prerequisite: Mc Eng 225. (Co-listed with Ae Eng 325)

327 Theory of Combustion (Lect 3.0) Application of chemical, thermodynamic, and gas dynamic principles to the combustion of solid, liquid, and gaseous fuels. Includes stoichiometry, thermochemistry, reaction mechanism, reaction velocity, temperature levels, and combustion waves. Prerequisite: Mc Eng 221. (Co-listed with Ae Eng 327)

329 Smart Materials and Sensors (Lect 2.0 and Lab 1.0) Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multi-disciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 204. (Co-listed with Ae Eng, E Mech, El Eng 329 and Cv Eng 318)

331 Thermofluid Mechanics II (Lect 3.0) Derivation of Navier-Stokes equations, exact solutions of some simple flows. Superposition methods for inviscid flows. Intermediate treatment of boundary layer theory, and gas dynamics. Introduction to turbulence and kinetic theory. Prerequisite: Mc Eng 231 or Ae Eng 231. (Co-listed with Ae Eng 331)

333 Internal Combustion Engines (Lect 3.0) A course dealing primarily with spark ignition and compression ignition engines. Topics include: thermodynamics, air and fuel metering, emissions and their control, performance, fuels, and matching engine and load. Significant lecture material drawn from current publications. Prerequisite: Mc Eng 221.

334 Theory of Stability I (Lect 3.0) Formulation of stability concepts associated with columns, beams, and frames. Applications to some engineering problems utilizing numerical methods. Prerequisites: Bas En 110; Math 204 & either Bas En 150 or E Mech 160. (Co-listed with E Mech 334, Ae Eng 334)

336 Fracture Mechanics (Lect 3.0) Linear elastic and plastic mathematical models for stresses around cracks; concepts of stress intensity; strain energy release rates; correlation of models with experiment; determination of plane stress and plane strain parameters; application to design. Prerequisite: Bas En 110. (Co-listed with E Mech 336, Ae Eng 336)

337 Atmospheric Science (Lect 3.0) An introductory survey designed to acquaint engineering and science students with the fundamentals of Atmospheric Science. Topics include atmospheric thermodynamics, synoptic scale disturbances, atmospheric aerosols (including cloud and precipitation physics), atmospheric electricity, and radiative transfer. Prerequisites: Mc Eng 221 or 227, or Ch Eng 141, or Chem 241, or Physics 311. (Co-listed with Physics 337)

338 Fatigue Analysis (Lect 3.0) The mechanism of fatigue, fatigue strength of metals, fracture mechanics, influence of stress conditions on fatigue strength, stress concentrations, surface treatment effects, corrosion fatigue and fretting corrosion, fatigue of joints, components and struc-

tures, design to prevent fatigue. Prerequisite: Bas En 110. (Co-listed with E Mech 337, Ae Eng 344)

339 Computational Fluid Mechanics (Lect 3.0) Introduction to the numerical solution of the Navier-Stokes equations, by finite difference methods, in both stream function-vorticity and primitive variable formulations. Course format emphasizes student development of complete computer programs utilizing a variety of solution methods. Prerequisites: Cmp Sc 73, one course in fluid mechanics. (Co-listed with Ae Eng 339)

341 Experimental Stress Analysis I (Lect 2.0 and Lab 1.0) Acquaints the student with some techniques of experimental stress analysis. Principal stresses, strain to stress conversion, mechanical and optical strain gages, electrical resistance strain gages, transducers, and brittle coatings. Prerequisite: Bas En 110. (Co-listed with E Mech 341, Ae Eng 341)

342 Experimental Stress Analysis II (Lect 2.0 and Lab 1.0) Acquaints the student with some techniques of experimental stress analysis. Topics include principal stresses, strain to stress conversion, transmission and reflection photoelastic methods, Moire fringe methods, and analogies. Prerequisites: Bas En 110, E Mech 321. (Co-listed with E Mech 342, Ae Eng 342)

343 Photographic Systems for Engineering Applications (Lect 2.0 and Lab 1.0) Study of photographic techniques applied to engineering uses including observations of events, recording and storage of data, and communication and dissemination of information. Both conventional and special photo-optical systems are covered. Prerequisite: Senior standing. (Co-listed with Ae Eng 343)

344 Interdisciplinary Problems in Manufacturing Automation (Lect 2.0 and Lab 1.0) The course will cover material necessary to design a product and the fixtures required to manufacture the product. Participants will gain experience with CAD/CAM software while carrying out an actual manufacturing design project. Prerequisite: Mc Eng 253 or approved courses in Ch Eng or Eng Mg. (Co-listed with Ch Eng 344, Eng Mg 344)

345 Non-Intrusive Measurement Methods (Lect 2.0 and Lab 1.0) Introduction to measurement methods useful to a mechanical engineer. Emphasis is placed on radiation measurement methods, including the effects of various sources and detectors. Prerequisite: Senior standing.

349 Robotic Manipulators and Mechanisms (Lect 2.0 and Lab 1.0) Overview of industrial applications, manipulator systems and geometry. Manipulator kinematics; hand location, velocity and acceleration. Basic formulation of manipulator dynamics and control. Introduction to machine vision. Projects include robot programming, vision-aided inspection and guidance, and system integration. Prerequisites: Cmp Sc 73, Mc Eng 213. (Co-listed with Ae Eng 349)

350 Integrated Product Development (Lect 2.0 and Lab 1.0) Students in design teams will simulate the industrial concurrent engineering development process. Areas covered will be design, manufacturing, assembly, cost, and product support. Using a 3-D solid modeling program, students will design, analyze, and send the data base to the automated machine shop where the parts will be manufactured. The parts will then be assembled, tested and analyzed for their performance. Prerequisites: Ae Eng 251 or Mc Eng 208 for Design; Mc Eng 213 for Assembly; Accompanied or preceded by Mc Eng 353 for Manufacturing; Eng Mg 375 or 385 for Cost/Product Support. (Co-listed with Ae Eng 350 and Eng Mg 350)

351 Intermediate Aerospace Structures (Lect 3.0) Discussion of the finite element method for static and dynamic analysis of complex aerospace structures. Solution of basic problems using established finite element computer programs. Prerequisite: Ae Eng 253 or Mc Eng 212. (Co-listed with Ae Eng 351)

353 Computer Numerical Control Manufacturing Processes (Lect 2.0 and Lab 1.0) Fundamental theory and application of computer numerical controlled machine tools from the viewpoint of design principles, machine structural elements, control systems, and programming. Projects include manual and computer assisted part programming and machining. Prerequisite: Mc Eng 253.

354 Variational Formulations of Mechanics Problems (Lect 3.0) Introduction and study of variational problems in classical dynamics and solid mechanics emphasizing the concepts of virtual work, minimum potential energy, and complementary energy. Variational inequalities. Prerequisites: Bas En 110 and Math 204; either Bas En 150 or E Mech 160. (Co-listed with E Mech 354)

355 Automation in Manufacturing (Lect 3.0) Current topics in manufacturing automation. Areas covered include: fixed automation, flexible automation, CNC devices, process planning and part programming, group technology, factory networks, and computer integrated manufacturing. Prerequisite: Mc Eng 253.

356 Design for Manufacture (Lect 3.0) Course covers the approach of concurrent product and process design. Topics includes: principle of DFM, New product design process, process capabilities and limitations, Taguchi method, tolerancing and system design, design for assembly and AI techniques for DFM. Prerequisites: Mc Eng 208, Mc Eng 253.

362 Experimental Vibration Analysis (Lect 2.0 and Lab 1.0) Methods for measuring and analyzing motion and strain response of dynamically excited structures. Includes frequency-response testing of elementary beam, torsion bar, plate and shell structures. Experiments on the effectiveness of isolators and dynamic absorbers. Prerequisites: E Mech 361 or Mc Eng 307 or Ae Eng 307. (Co-listed with Ae Eng 362, E Mech 362)

363 Computer Applications in Mechanical Engineering Design (Lect 2.0 and Lab 1.0) Introduction to computer aided design, personal comput-

er graphics to introduce main frame graphics and analysis programs. Fundamentals of finite element analysis are discussed. Projects include basic graphics, drafting, area, mass and inertia properties analysis, matrix algebra and finite element analysis of solid mechanics problems using educational and commercial software. Prerequisites: Cmp Sc 73, 77, Mc Eng 211, 208.

365 Solar Heating and Cooling (Lect 3.0) A review of heat transfer and the nature of solar radiation. Methods of collecting and storing solar energy. Analysis and design of systems for heating and cooling by solar energy. Prerequisite: Mc Eng 225.

367 Heat Pump and Refrigeration Systems (Lect 3.0) The various methods used in the thermal design and analysis of both refrigeration and heat pumps systems are investigated. Various methods of producing heating and cooling are examined including vapor compression, absorption, air cycle, steam jet, and thermoelectric systems. Prerequisites: Mc Eng 221, 225.

371 Environmental Control (Lect 3.0) Theory and applications of principles of heating, ventilating, and air conditioning equipment and systems; design problems. Physiological and psychological factors relating to environmental control. Prerequisites: Mc Eng 221 and accompanied or preceded by Mc Eng 225.

373 Thermal System Analysis (Lect 3.0) The usage of simulation, optimization, and computer-aided design in thermal systems. Power generation, heating and refrigeration, and other complete thermal process systems are analyzed considering all factors which affect the design optimization of the system. Prerequisites: Mc Eng 221, 225.

375 Mechanical Systems for Environmental Control (Lect 3.0) Analysis of refrigeration, heating, and air-distribution systems. Synthesis of environmental control systems. Prerequisites: Mc Eng 221, 225.

377 Environmental Quality Analysis and Control (Lect 3.0) Study of the thermal and particulate effluents of engineering systems, such as engines, fossil-fuel fired, and nuclear power plants. Investigation of the techniques for measurement and control of combustible and particulate discharges. Development of stochastic models and other comprehensive techniques for prediction of particulate and energy transport and distribution phenomena.

379 Fluid Systems and Controls (Lect 3.0) Analysis and design of pneumatic, fluidic, and hydraulic power and control systems, particular emphasis on the basic mechanics of pneumatic and fluidic components and systems. Prerequisites: Mc Eng 231, 279.

381 Mechanical and Aerospace Control Systems (Lect 3.0) Synthesis of mechanical and aerospace systems to perform specific control functions. Response and stability are studied. Singular value analysis for stability margins is introduced. Prerequisite: Mc Eng 279 or Ae Eng 361. (Co-listed with Ae Eng 381)

382 Introduction to Composite Materials & Structures (Lect 3.0) Introduction to fiber-reinforced composite materials and structures with emphasis on analysis and design. Composite micromechanics, lamination theory and failure criteria. Design procedures for structures made of composite materials. An overview of fabrication and experimental characterization. Prerequisite: Bas En 110. (Co-listed with E Mech 381 and Ae Eng 311)

383 Industrial Applications of Composite Materials Technology (Lect 3.0) Composite materials-industrial applications. Fibers and matrices. Fabrication and NDI. Lamination theory overview. Composite joints. Postbuckling. Fatigue and environmental effects. Testing and certification of composite structures. A majority of the presentations will be made by engineers in the industry. Prerequisite: Bas En 110. (Co-listed with E Mech 303)

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course. Variable title. (Co-listed with Ae Eng 401)

407 Advanced Vibrations (Lect 3.0) Advanced treatment of discrete and continuous vibratory systems. Extensive use is made of matrix methods and operator notation. Special topics include: transmission matrices, relative coordinates, time dependent boundary conditions, approximate techniques for linear systems, nonlinear systems, and random excitations. Prerequisite: Mc Eng or Ae Eng 307 or E Mech 361. (Co-listed with Ae Eng 407)

408 Finite Element Approximation II-Second Course (Lect 3.0) Continuation of Finite Element Approximation I-An Introduction; element selection and interpolation estimates, Lagrange, Hermite, and Isoparametric elements; mixed, hybrid, penalty and boundary elements; engine value and time-dependent problems; three-dimensional and nonlinear problems. Prerequisite: E Mech 307 or Mc Eng 312 or Ae Eng 352. (Co-listed with E Mech 408, Ae Eng 408)

409 Engineering Acoustics II (Lect 3.0) Expanded treatment of the theory of sound generation and propagation. The acoustic source, dipole, and quadrupole. Noise sources due to vibration and fluid flow. Sound propagation in the atmosphere. The transmission of sound in ducts. Propeller, fan, and jet noise. Prerequisite: Mc Eng or Ae Eng 309. (Co-listed with Ae Eng 409)

410 Seminar (Variable) Discussion of current topics. (Co-listed with Ae Eng 410 and E Mech 410)

413 Advanced Dynamics of Machinery (Lect 3.0) Current problems in aerospace dynamics are treated using methods of analytical mechanics;

gyroscopic phenomena; the calculus of variations; stability of systems, to include approximate techniques. Prerequisite: Mc Eng or Ae Eng 313. (Co-listed with Ae Eng 413)

419 Microscopic Thermodynamics (Lect 3.0) A microscopic treatment of thermodynamic concepts using the statistical approach. The kinetic theory of an ideal gas including transport phenomena. A comprehensive introduction to Maxwell-Boltzmann and quantum statistics including the relationship between particular functions and thermodynamic properties. An introduction to the ensemble method of Gibbs for systems of dependent particles. Prerequisite: Mc Eng or Ae Eng 319. (Co-listed with Ae Eng 419)

423 Viscous Fluid Flow (Lect 3.0) Fundamentals of viscous fluids for incompressible and compressible flows governed by Navier-Stokes equations; exact, approximate, and numerical solutions for steady and unsteady laminar flows; stability, transition, and turbulence, CFD simulations of internal and external flows. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Ae Eng 423)

424 Theory of Stability II (Lect 3.0) Buckling of plates and shells, dynamic stability of elastic systems, and nonconservative systems. Prerequisite: E Mech 334 or Mc Eng 334 or Ae Eng 334. (Co-listed with E Mech 435)

425 Heat Transfer by Conduction (Lect 3.0) A study of conduction heat transfer in solids by analytical and other methods. Prerequisite: Mc Eng or Ae Eng 325. (Co-listed with Ae Eng 425)

427 Heat Transfer by Convection (Lect 3.0)An analytical study of convective heat transfer in laminar and turbulent flows; forced convection, natural convection, and mixed convection; combined heat and mass transfer; heat transfer with change of phase; instability of laminar flow; current topics in convection. Prerequisite: Mc Eng or Ae Eng 325. (Co-listed with Ae Eng 427)

429 Heat Transfer by Radiation (Lect 3.0) A study of the nature of thermal radiation; implications from electromagnetic theory; radiative characteristics of surfaces; enclosures; configuration factors; radiosity; specular and diffuse reflection; transfer in absorbing, emitting and scattering media; combined radiation conduction and convection; experimental methods. Prerequisite: Mc Eng or Ae Eng 325. (Co-listed with Ae Eng 429)

430 Theory of Plates (Lect 3.0) General coverage of various approaches to plate problems and the application of these methods to practical problems. Special topics include applications to elastic foundations, buckling and energy methods in plate theory. Prerequisite: Math 325. (Co-listed with E Mech 431)

431 Gas Dynamics I (Lect 3.0) A critical analysis of the phenomena governing the flow of a compressible fluid; introduction to flow in two and three dimensions; Prandil-Meyer expansions; small perturbations in subsonic and supersonic flows; method of characteristics. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Ae Eng 431)

432 Theory of Shells (Lect 3.0) General theory of stress analysis of shells based on topics in differential geometry and general elasticity theory. Theory is applicable to studies of the elastic behavior of flat plates and shells, buckling and post-buckling behavior of shells, and provides a basis for all shell theories which account for anisotropy, plasticity, creep, thermal strains, internal reinforcements, and transverse shearing deformations. Prerequisite: Math 325. (Co-listed with E Mech 432)

433 Gas Dynamics II (Lect 3.0) A continued study of compressible fluid flow phenomena; bodies of revolution and slender body theory; transonic flow; unsteady one-dimensional motion including small amplitude waves, continuous flow, and shock waves; the shock tube; shockwave boundary layer interactions. Prerequisite: Mc Eng or Ae Eng 431. (Co-listed with Ae Eng 433)

435 Turbulence in Fluid Flow (Lect 3.0) Fundamentals of statistical theory of turbulence; turbulence modeling for transport processes of heat, mass, and momentum; closure schemes for Reynolds-averaged Navier-Stokes equations in free turbulence and wall turbulence; CFD simulations of turbulent flows. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Ae Eng 435 and Ch Eng 435)

436 Advanced Fracture Mechanics (Lect 3.0) Mathematical theories of equilibrium cracks and brittle fracture, mathematical analysis of elastic-plastic fracture mechanics, COD, R-curve and J-integral analysis. Prerequisite: Ae Eng 336 or E Mech 336 or Mc Eng 336. (Co-listed with E Mech 436)

437 Physical Gas Dynamics I (Lect 3.0) Features of high temperature gas flows including the development of the necessary background from kinetic theory, statistical mechanics, chemical thermodynamics and chemical kinetics. Equilibrium and non-equilibrium gas properties and gas flows are included. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Ae Eng 437)

439 Physical Gas Dynamics II (Lect 3.0) Features the study of transition regime gas dynamics including the concept of molecular velocity distribution, gas-solid interaction, the Boltzmann equation, nonequilibrium flow and solutions to specific problems in transition flow. Prerequisite: Mc Eng or Ae Eng 331. (Co-listed with Ae Eng 439)

441 Advanced Energy Conversion (Lect 3.0) An analytical study of power producing systems with emphasis on new techniques and energy sources. All basic methods of energy conversion are covered from detailed physical descriptions to mathematical analysis. Included are advanced heat engines, nuclear power reactors, thermoelectric engines, magnetohydrodynamic devices, solar energy, fuel cells, and recent developments. Prerequisite: Mc Eng (or Ae Eng) 319, or Mc Eng (or Ae Eng) 325

443 Engineering Magnetohydrodynamics (Lect 3.0) Critical study of magnetohydrodynamic power generation and magnetohydrodynamic propulsion; including the study of ionization processes, gaseous conduction, fundamental equations of magnetohy-

drodynamics, exact solutions of magnetohydrdynamic channel flow, one dimensional approximation, boundary layer development and important parameters in magnetohydrodynamics. Prerequisite: Math 322. (Co-listed with Ae Eng 443)

451 Thermal Stresses I (Lect 3.0) Review of conduction heat transfer principles and formulation of fundamental thermal stress relations with closed form and finite element solution of some basic practical problems. Prerequisite: Mc Eng 325. (Co-listed with Ae Eng 451)

453 Advanced CNC of Manufacturing Processes & Engineering Metrology (Lect 2.0 and Lab 1.0) Advanced treatment of Computer Numerical Control (CNC) part programming and machine tool metrology. Topics include mathematical modeling and characterization of machine tools and Coordinate Measuring Machines (CMMs); Measurement and analysis of dimensional accuracy, surface finish, precision, and uncertainty; Machine tool error modeling and compensation; Virtual Numerical Control (VNC) Machine Tool modeling, programming, simulation and process verification/optimization. Projects include advanced CNC programming and simulation. Prerequisite: Mc Eng 353.

455 Structures and Materials for Extreme Environments (Lect 3.0) An advanced course in the types and selection of materials and structures with emphasis on the underlying theory of their behavior. Lubrication in the vacuum of space and ablation; recent developments in materials and fabrication techniques. Effects of vacuum radiation, corrosive agents, temperature. (Co-listed with Ae Eng 455)

459 Advanced Topics in Design and Manufacturing (Lect 3.0) Various topics in the area of design and manufacturing will be covered in this course: development of flexible manufacturing systems, CAD/CAM integration, rapid prototyping, etc. Prerequisite: Mc Eng 355.

475 Advanced Environmental Control (Lect 3.0) The study of environmental control systems including their sizing, control, and energy requirements. Use of major energy analysis programs for system evaluation. Prerequisite: Mc Eng 375.

479 Analysis and Synthesis of Mechanical and Aerospace Systems (Lect 3.0) A unified treatment of modern system theory for the Mechanical and Aerospace Engineering Controls Analyst, including analysis and synthesis of linear and nonlinear systems, compensation and optimization of continuous and discrete systems, and theory of adaptivity. Prerequisite: Mc Eng 381 or Ae Eng 381. (Co-listed with Ae Eng 479)

483 Aerosol Mechanics & Low Reynolds Number Hydrodynamics (Lect 3.0) Aerosol (hydrosol) particle motion under the influence of external forces (inertial, gravitational, electrostatic, phoretic, etc.) particle coagulation, deposition, filtration theory applied to clean rooms. Prerequisite: Mc Eng or Ae Eng 331 or Ch Eng 336.

484 Analysis of Laminated Composite Structures (Lect 3.0) An overview of isotropic beams, plates, and shells. Bending, vibration, and buckling of laminated composite beams and plates: exact and approximate solutions. Development of composite shell theory and simplified solutions. Analysis of composite structures including transverse shear deformation and thermal effects. Prerequisite: E Mech 381 or Mc Eng 382 or Ae Eng 311. (Co-listed with E Mech 484 and Ae Eng 484)

485 Mechanics of Composite Materials (Lect 3.0) Effective moduli of spherical, cylindrical, and lamellar systems. Micromechanics of fiber-matrix interfaces and unidirectional composites. Application of shear leg and other approximate theories to interfaces and composites including fiber pullout, debonding and matrix cracking. Prerequisite: E Mech 381 or Mc Eng 382 or Ae Eng 311. (Co-listed with E Mech 483 and Ae Eng 485)

487 Finite Element Approximation III - Nonlinear Problems (Lect 3.0) Formulation of nonlinear problems, iterative methods, solution of nonlinear problems, cover topics of interest to the class. Prerequisite: E Mech 408 or Mc Eng 408 or Ae Eng 408. (Co-listed with E Mech 487 and Ae Eng 487)

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

491 Internship (Variable) Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

METALLURGICAL ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

303 New Developments in Chemical Metallurgy (Variable) Survey of selected modern processes for the production of metals, the treatment of wastes, and recycling of metal values. Processes are studied with respect to raw materials, chemical reactions, energy consumption, process intensity, yield and environmental impact. Prerequisite: Mt Eng 203.

305 Nondestructive Testing (Lect 2.0 and Lab 1.0) Principles and application of various means of nondestructive testing of metallic materials. Radiological inspection methods, ultrasonic testing, magnetic methods, electrical and eddy current methods, and others. In addition, laboratory exercises using industrial grade NDT equipment to inspect a variety of parts and materials. Prerequisites: Physics 24 or 25.

306 Nondestructive Testing Laboratory (Lab 1.0) Application of radiological and ultrasonic methods of nondestructive testing of metallic materials. A radiographic X-ray units and ultrasonic equipment are used in the inspection of a variety of materials and manufactured parts. Prerequisite: Accompanied or preceded by Mt Eng 305.

307 Metals Casting (Lect 2.0) An advanced course in the materials and methods used in modern metals casting processes. Application of metallurgical principles to the casting of metals. Prerequisite: Mt Eng 221 or Mc Eng 153.

308 Metals Casting Laboratory (Lab 1.0) An advanced laboratory study of mold materials, metal flow, and cast metals. Emphasis is given to design of gating, risering, and ladle treatment techniques required for economical, highquality castings. Prerequisite: Accompanied or preceded by Mt Eng 307.

310 Seminar (Variable) Discussion of current topics.

311 Metals Joining (Lect 2.0) Metals joining processes such as welding and brazing. Effects of welding on materials. Treatment and properties of welded joints. Welding defects and quality control. Prerequisite: Mt Eng 121 or 221.

313 Scanning Electron Microscopy (Lect 2.0 and Lab 1.0) A course in the theory and application of scanning electron microscopy and x-ray microanalysis. Topics considered are electron optics, image formation and analysis; x-ray generation, detection and analysis; and characterization of fracture surfaces. Prerequisites: Mt Eng 215 and 216 or course in optical microscopy - consent of instructor required.

315 Metallurgical Process Design Principles (Lect 2.0) Application of mass, component and energy balances for metallurgical design. The fundamentals of engineering economic analysis will be examined and experimental design techniques will be introduced. Students will be prepared for the selection and planning of the subsequent design project. Prerequisite: Senior standing in Mt Eng.

316 Metallurgical Design Project (Lab 2.0) Student groups will undertake selected projects, which will represent a capstone design experience utilizing skills, understanding and data from previous courses. The faculty supervised open-ended design projects will involve a variety of tasks appropriate to the metallurgical engineer. Prerequisite: Mt Eng 315.

321 Metal Deformation Processes (Lect 3.0) An introduction to metal deformation concepts followed by a study of various forming processes from both the analytical and applied viewpoints. Processes to include: forging, wire drawing, extrusion, rolling, sheet metal forming, and others. Prerequisite: Mt Eng 221.

325 Fundamentals of Materials Behavior I (Lect 3.0) Introduces students without a metallurgical background to the physical, chemical and structural basis of the equilibrium behavior of materials. Includes thermodynamic potentials, phase equilibria, phase diagrams and their relation to microstructure and chemical thermodynamics of condensed phases. Prerequisites: Graduate standing, Math 204, Physics 107. (Not for metallurgy majors) (UMR Engineering Education Center, St. Louis only).

327 Fundamentals of Materials Behavior II (Lect 3.0) A continuation of Metallurgy 325 emphasizing the kinetic processes involved in materials behavior. Concepts of the theory of absolute reaction rates, diffusion in metallic solids, elementary dislocation theory, plastic deformation, crystallization solid state phase transformations. Prerequisite: Mt Eng 325. (Not for metallurgy majors) (UMR Engineering Education Center, St. Louis only).

329 Material Selection, Fabrication, and Failure (Lect 3.0) Factors governing the selection of materials for specific needs, fabrication, heat treatment, surface treatment, and other aspects in the production of a satisfactory component. Failure analysis and remedies. Lecture plus assigned problems. Prerequisites: Mt Eng 217, 218, 221.

331 Steels and Their Treatment (Lect 3.0) Industrially important ferrous alloys are described and classified. The selection of proper heat treatments to facilitate fabrication and to yield required service properties in steels suitable for various applications is considered. Prerequisites: Mt Eng 271, 218.

332 Metals Treatment Laboratory (Lab 1.0) The students plan and perform experiments that illustrate heat treating processes and their effects on the properties and structure of commercial alloys. Prerequisite: Accompanied or preceded by Mt Eng 331.

333 Nonferrous alloys (Lect 3.0) Structure and properties of nonferrous alloys (Al, Ti, Mg, Ni and Cu) are described. The role of processing and microstructure in the development of mechanical properties is emphasized. Prerequisites: Mt Eng 217 or Mt Eng 377.

341 Nuclear Materials I (Lect 3.0) Fundamentals of materials selection for components in nuclear applications. Design and fabrication of UO2 fuel; re-

actor fuel element performance; mechanical properties of UO2; radiation damage and effects, including computer modeling; corrosion of materials in nuclear reactor systems. Prerequisite: Nu Eng 205. (Co-listed with Nu Eng 341)

343 Nuclear Materials II (Lect 3.0) Extractive metallurgy of uranium, thorium, and zirconium. Equation of state of UO2 and fuel chemistry. LMFBR fuel and interaction of sodium and stainless steel. Materials for fusion and other advanced nuclear applications. Reprocessing of spent fuel and disposal. Prerequisite: Mt Eng 341.

350 Composites (Lect 3.0) An introduction to the structure, properties and fabrication of fiber and particulate composites. Prerequisites: Mt Eng 215 & 211 or Cr Eng 102 & 242.

351 Mineral Processing II (Flotation and Hydrometallurgy) (Lect 2.0 and Lab 1.0) Froth flotation including mineral surfaces, double layer theory, zeta potential, hydrophobicity, adsorption, collectors, frothers, modulation, kinetics, and sulphide and acid flotation systems. Hydrometallurgy including leaching, ion exchange and liquid/liquid extraction. Prerequisite: Mt Eng 241.

353 Mineral Processing II (Mechanics and Design) (Lect 2.0 and Lab 1.0) Mineral particle mechanics of comminution, sizing, classification, concentration, filtering and thickening. Mill and equipment selection and design including flowsheet development and plant assessment. Prerequisite: Mt Eng 241.

354 Metallurgical Process Simulation and Control (Lect 1.0 and Lab 1.0) Simulation of metallurgical processes through the use of theoretical and empirical models, numerical methods, and analog representation. Introduction to instrumentation, computer interfacing and process control theory. Prerequisites: Mt Eng 121, 125, 126.

355 Metallurgical Thermodynamics II (Lect 2.0 and Lab 1.0) Continuation of metallurgical engineering 281. Equilibrium calculations with stoichiometry and heat balance restrictions. Phase transformation, solution thermodynamics and partial molar properties. Applications of thermo-dynamics to the analysis and design of extractive and physical metallurgy processes. Computer calculations of complex equilibria. Prerequisite: Mt Eng 203.

356 Principles of Extractive Metallurgy (Lect 3.0) Application of thermodynamics, heat and mass balances, and kinetics to the understanding, analysis, and design of metal extraction processes. Use of stability and phase diagrams to analyze existing processes and design new ones. Prerequisite: Mt Eng 355.

358 Steelmaking (Lect 3.0) Introduction to the fundamentals and unit processes used to turn impure iron and scrap into steel. Includes desulfurization, BOF and electric furnace operations, ladle metallurgy, casting, and stainless steel manufacture.

359 Environmental Aspects of Metals Manufacturing (Lect 3.0) Introduction to environmental aspects of metal extraction, melting, casting, forming, and finishing. Subjects include history of environmental movement and regulations permitting, risk analysis, disposal and recycling of metal manufacturing residues, environmental ethics, environmental technologies and case studies. Prerequisite: Junior/Senior standing.

360 Materials Selection & Fabrication (Lect 2.0) Factors governing the selection of materials, including metals, ceramics, polymers and composites, for specific need. Fabrication of materials. Prerequisites: Mt Eng 215 & 211 or Cr Eng 102 & 242.

361 Alloying Principles (Lect 3.0) Basis for alloy design and property control. Predictions of phase stability, alloy properties and metastable phase possibilities; interfaces in solids and their role in phase transformations. Prerequisites: Mt Eng 217, 218.

363 Metal Coating Processes (Lect 3.0) Introduction to the current technologies used to enhance metal performance, particularly corrosion resistance, by overlay coatings. Deposition processes are emphasized and the fundamentals of the behavior of the films in high technology and electronic materials applications is discussed. Prerequisites: Mt Eng 202, 203.

367 Introduction to Powder Metallurgy (Lect 2.0 and Lab 1.0) A survey of the powder metallurgy field, from fabrication of powders to finishing operations. Includes all basics of powder metallurgy and many new processes currently used in industry. Also covers design, production, economics and energy concerns. Hands-on laboratory time is included. Prerequisites: Mt Eng 217, 218.

368 Physical Metallurgy III Laboratory (Lab 1.0) Experiments in physical metallurgy including internal friction, precipitation hardening, order-disorder transformations, plastic deformation and thermal expansion.

375 Metallurgical Failure Analysis (Lect 3.0) Application of the principles of manufacturing and mechanical metallurgy for the analysis of failed components. Analytical techniques such as Scanning Electron Microscopy, Optical Metallography, and High Resolution Photography are used to characterize microstructure and fractographic features. In addition, appropriate methods to gather data, assimilate it, and draw conclusions from the data such that it will stand up in a court of law will be addressed. Prerequisite: Senior or Graduate Student standing.

377 Principles of Engineering Materials (Lect 3.0) Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Ae Eng 377, Ch Eng 377, Physics 377, Cr Eng 377)

385 Mechanical Metallurgy (Lect 3.0) Elastic and plastic behavior of metallic single crystals and polycrystalline aggregates. Resulting changes in

mechanical properties are considered. Included are applications to metal fabrication. Prerequisites: Mt Eng 215, 216, Bas En 110.

390 **Undergraduate Research** (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

400 **Special Problems** (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 **Special Topics** (Variable) This course is designed to give the department an opportunity to test a new course. Variable title.

402 **Advanced Mechanical Metallurgy** (Lect 3.0) An advanced study of the effect of elastic and plastic deformation on metal single crystals and polycrystalline aggregates. Brittle behavior, workhardening and the development of directional properties in metals. Prerequisite: Mt Eng 385 or appropriate academic or industrial experience.

403 **High Temperature and Corrosion Resistant Alloys** (Lect 3.0) Fabrication and use of nickel, titanium, and refractory metal based alloys for use at high temperatures or in chemically corrosive environments. Properties and strengthening mechanisms of these alloys. Theory of high temperature oxidation and corrosion and design of alloys to prevent them. Prerequisites: Mt Eng 217, 218.

404 **Recent Advances in Extractive Metallurgy** (Lect 2.0) A survey of extractive processes recently developed in the light of modern requirements with respect to raw materials, product quality, environmental impact, energy consumption, capital cost and process control. Prerequisite: Mt Eng 355.

407 **Powder Metallurgy** (Lect 2.0) Production of metal powders, and the consolidation of powders into solid forms. Sintering, homogenization, and plastic deformation of the compacts as applied to the production of metals and alloys. Prerequisites: Mt Eng 217, 218.

409 **The Structure of Metals** (Lect 3.0) Principles governing the crystal structure of metals and alloys and the effect of structure upon the mechanical and physical properties of commercial metals and alloys. A general theory of dislocations and their behavior is included. Prerequisite: Mt Eng 217.

410 **Seminar** (Variable) Discussion of current topics.

414 **Transmission Electron Microscopy** (Lect 2.0 and Lab 1.0) A course in the theory and application of transmission electron microscopy. Topics considered are electron optics, image formation, defect structures, specimen preparation, contrast theory and electron diffraction. Prerequisite: Mt Eng 313.

415 **Advanced Physical Metallurgy, Phase Transformations** (Lect 3.0) Fundamentals of phase transformations which proceed by nucleation and diffusional growth discussed in the light of recent research; nucleation and growth theory leading to an understanding of the morphology of microstructures; transformation, precipitation, spinodal decompositions, massive transformation. Prerequisites: Chem 243, Mt Eng 355.

421 **Ferrous Metals Casting** (Lect 2.0) An advanced study of the metallurgy of cast irons. Includes theories of nucleation and growth in gray, nodular, and malleable irons. The effects of alloying elements and processing variables on solidification, heat treatment, and properties of cast irons are examined.

427 **Diffusion** (Lect 3.0) Advanced discussion of phenomenological and atomistic theories of diffusion: diffusion mechanisms; diffusion in metals and alloys; diffusion in nonmetals; chemical diffusion; high diffusivity paths; pressure dependence of diffusion; diffusion in an electric field; diffusion-controlled processes such as internal friction. Prerequisite: Mt Eng 361.

429 **Advanced Materials Selection and Fabrication** (Lect 3.0) Application of the principles of material selection and the factors governing fabrication, heat treatment, and surface treatment. Weekly assignments requiring library research and written reports. Lecture plus classroom discussion of assigned problems.

431 **Gas-Metal Reactions** (Lect 2.0) The thermodynamics of gas-metal reactions in controlled atmospheres used in heat treating and surface treatment of metals and alloys. Prerequisites: Mt Eng 217, 218, Chem 243.

451 **Refining of Metals** (Variable) Principles and applications of thermochemistry, phase equilibria, and kinetics as applied to the refining of metals and alloys. Theory of dilute solutions, interaction coefficients and reactions of metals with gases and slags. Analysis and design of refining processes. Optional third credit hour requires a term paper. Prerequisite: Mt Eng 355 or Cr Eng 259.

454 **Metallurgical Process Simulation and Control** (Lect 2.0 and Lab 1.0) A graduate course dealing with process simulation, instrumentation and process control in process metallurgy. The student is required to build computer models of metallurgical and engineering processes, interface instrumentation with data acquisition systmes and to demonstrate and solve process control problems utilizing mathematical techniques and interactive computer programs.

455 **Chemical Metallurgy** (Lect 3.0) The theory and application of basic chemical principles to the extraction, refining and general chemical behavior of metals and alloys. Independent study project will focus on process design options emphasizing environmental aspects of flow sheet development. Prerequisites: Physics 107, Chem 243.

457 **Transport Phenomena in Extractive Metallurgy** (Lect 3.0) The application of chemical reaction engineering principles to metallurgical processes. Residence-time districation in reactors and its effect on performance, topochemical gas-solid reactors, two-film theory of mass transfer applied to slag-metal and gas-metal reactions. Prerequisite: Mt Eng 355 or equivalent.

459 Advanced Environmental Aspects of Metallurgy (Lect 3.0) Studies of environmental aspects of metal extraction, melting, refining, casting, and forming. Subjects covered will include regulations, permitting, risk analysis, disposal and recycling. Prerequisite: Graduate standing.

478 Thermodynamics and Kinetics of Materials (Lect 4.0) The principles and applications of solution thermodynamics and kinetics are discussed relative to materials systems to explain phase equilibria, chemical processes and phase transformations. Topics considered include phase diagrams, gas-solid reactions, liquid-solid reactions, diffusion, reaction rate theory, conductivity in ceramics, nucleation and growth during phase transformation. Prerequisite: Graduate Standing.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

MINING ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

302 Computer Applications in the Mining & Minerals Industry (Lect 2.0 and Lab 1.0) History of computer technology usage in the mining industry. Exposure to the use of computers in mine planning, design, exploration, ventilation & environment, rock mechanics, open pit stability, simulation of mining systems and equipment selection.

305 Explosives Handling and Safety (Lect 1.0) Basic handling & safety for explosives, explosive devices and ordnance related to laboratory handling, testing, manufacturing & storage, for both civil and defense applications. For "credit offering" of the UMR Explosives Handling & Safety Industrial Short Course.

306 Material Processing by High-Pressure Water Jet (Lect 3.0) Methods of generating high pressure water jets; standard equipment, existing techniques and basic calculations. Applications of water jets to materials cutting and mineral processing. Safety rules. The course will be supported by laboratory demonstrations. (Co-listed with Mc Eng 306)

307 Principles of Explosives Engineering (Lect 2.0 and Lab 1.0) Theory and application of explosives in the mining industry; explosives, initiating systems, characteristics of explosive reactions and rock breakage, fundamentals of blast design, drilling and blasting, regulatory and safety considerations. Prerequisites: Ge Eng 50; accompanied or preceded by either Cv Eng 215 or Geo 220.

308 Drilling and Blasting (Lect 1.0 and Lab 1.0) The mechanics of rock breakage in drilling and blasting. Drill equipment systems, and the application of engineering principles in the design of blasting rounds for construction and mining excavation problems. Prerequisite: Mi Eng 307.

311 Mine Plant Management (Lect 2.0) Optimization of mine plant and equipment performance. Availability, utilization and reliability of equipment; matching equipment and plant to minesite specific conditions; maintenance planning, scheduling and control; parts and materials supply systems; mine information and management systems. Basics of mine automation and robotics. Prerequisite: Senior standing or consent of instructor.

317 Mining Equipment Design and Maintenance (Lect 2.0 and Lab 1.0) This course will teach the basic understanding of mining machine design principles with special attention placed on kinematics, assembly and disassembly as well as maintenance procedures and techniques involved. Prerequisite: Mi Eng 217.

318 Mine Atmospheric Control II (Lect 2.0 and Lab 1.0) Climatic measurements and temperature precalculations, emergency plans for fan failures and mine fires, mine air contaminants, mine noises, mine dust, refrigeration and cooling plant layout, radiation control. Prerequisite: Mi Eng 218.

322 Mine Management (Lect 2.0) Theory and practice of mine management, including basic managerial functions, management theories, communication skills, motivation, leadership, organization, maintenance management, managerial decision making, cost control, labor relations, government relations, ethics, with emphasis in presentation skills. Prerequisite: Completion of 120 credits in Mining Engineering curriculum.

325 Mining Methods for Metal and Industrial Minerals (Lect 4.0) The process of developing metallic and industrial mineral deposits into productive entities. Principles of planning, constructing, and operating economically viable underground and surface mines. Cost effective mining methods and equipment selection. Principles of operation and coordination of mining projects. Stoping methods, benching methods. Prerequisites: Mi Eng 221, 270.

343 Coal Mine Development and Production (Lect 3.0) An in-depth study of all aspects of coal mining, including an overview of coal industry, reserves and geology, planning and development of coal mines, surface and underground mechanized methods of face preparation, equipment, coal extraction, handling and preparation as practiced in the United States. Prerequisite: Accompanied or preceded by Mi Eng 217.

344 Coal Preparation (Lect 2.0 and Lab 1.0) Coal properties, sampling, testing, breaking, sizing, cleaning and dewatering. Disposal of refuse. Prerequisites: Mt Eng 241 and senior standing.

345 Strata Control (Lect 3.0) A detailed review of artificial ground support, both above and below ground, including slope stabilization techniques and shaft and tunnel liner design. The use of shotcrete, roofbolts, and solid liners and the principles of underground longwall and room and pillar mine support. Longwall and hydraulic mining practice is covered. Prerequisite: Mi Eng 231.

350 Blasting Design and Technology (Lect 2.0 and Lab 1.0) Advanced theory and application of explosives in excavation; detailed underground blast design; specialized blasting including blast casting, construction and pre-splitting. Introduction to blasting research. Examination of field applications. Prerequisite: Mi Eng 307.

370 Valuation of Mineral Properties (Lect 3.0) Engineering principles utilized for establishing values of metallic, fuel, and industrial mineral deposits; reserve estimation from exploration samples, geostatistics; mine taxation; influence and sensitivity analyses; alternative valuation techniques. Prerequisite: Mi Eng 270.

376 Mined-Land Reclamation (Lect 3.0) Permitting: the legal environment of reclamation and environmental impact assessment; post-mining land-use selection and mine planning for optimum reclamation of all mines: metal, non-metal, and coal; unit operations of reclamation: drainage, backfill, soil replacement, revegetation, maintenance, etc. Prerequisites: Ge Eng 50 and prerequisite or corequisite, one of Ge Eng 246, Cv Eng 215 or Mi Eng 226. (Co-listed with Ge Eng 376)

383 Tunneling & Underground Construction Techniques (Lect 2.0 and Lab 1.0) Cover both mechanical excavation and conven-tional excavation techniques to underground tunneling and construction. The emphasis will be on equipment selection and prediction of performance expected of the equipment. Ground control systems will be covered as technology emerges. Excavation methods and support of large caverns, often found in civil structures, will also be discussed. A limited focus will be on underground construction specifications and underground advance rate and cost estimation techniques. Prerequisites: Mi Eng 231, Mi Eng 325 or Cv Eng 215, Cv Eng 216 or Ge Eng 371.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

393 Mine Planning and Design (Lect 2.0 and Lab 2.0) Selection of a mining design project that results in the preparation of a comprehensive engineering report and oral presentation for the economic exploitation of the selected geologic deposit. The course includes instruction and student guidance that integrates and applies engineering economics, sciences, use of commercial software & principles to develop a mineable deposit. Prerequisite: Completion of 120 hours in Mining Engineering curriculum.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

402 Environmental Controls for Blasting (Lect 2.0 and Lab 1.0) Advanced blast mechanics; overbreak control including comprehensive coverage of perimeter and smoothwall specialist blasting techniques and geotechnical factors affecting blast vibration, limits analysis monitoring and control; air blast control including limits, monitoring and atmospheric and topographic effects. Prerequisite: Mi Eng 307.

404 Advanced Mining Systems (Lect 3.0) Principles of design for the development and production of hard rock mineral deposits that require integrated surface and underground mining methods. Cost considerations leading to optimization. Terminal feasibility report required. Prerequisites: Mi Eng 224, 226 and 393.

405 Non-Explosives Rock Fragmentation (Lect 2.0 and Lab 1.0) Modern methods of geotechnical excavation are discussed. These include drills, plows, shearers, roadheaders, impact breakers, and tunnel boring machines, together with thermal cutting, electron beam, the REAM concept and waterjet cutting whether by plain, cavitating, abrasive-laden, or mechanically assisted jets.

406 Scientific Instrumentation for Explosives Testing & Blasting (Lect 2.0 and Lab 1.0) Application of scientific principles, equipment description and operation for instrumentation of explosive events including blasting. Topics: Blast chamber design, set up, high-speed photography, motion detection and measurement, explosives sensitivity testing, explosives properties testing, vibration measurement & analysis, destruction & demilitarization.

407 Theory of High Explosives (Lect 3.0) Study of the application of chemical thermodynamics and the hydrodynamic theory to determine properties of high explosives; kinetics and reaction rates; application of the above to the blasting action of explosives. Prerequisite: Mi Eng 307.

408 Ore Reserve Analysis and Geostatistics (Lect 2.0 and Lab 1.0) An introduction to principles of geostatistics, theory of spatially correlated ran-

dom variables, variance and co-variances and their application on the evaluation of mineral resources, ore reserve estimation, strategic exploration, and production planning. Real case studies from mining industry will be presented. Prerequisite: Mi Eng 270.

409 Mining Property Feasibility Studies and Evaluation Procedure (Lect 2.0 and Lab 1.0) A systematic phased approach is presented, designed to increase the level of confidence and accuracy of estimates, moving from exploration through to a "bankable" study. Liability, ethics, resource/reserves, political/social/investment risk, economic parameters, and due diligence are discussed. Prerequisite: Mi Eng 270 or Geo 294 or Cv Eng 241 or Eng Mg 208 or Mi Eng 376 or Geop 382.

410 Seminar (Lect 1.0) Discussion of current topics.

415 Advanced Mineral Engineering Design I (Lect 3.0) Principles of design of coal, metal, and other mines and associated operations, with emphasis on environmental protection and the health and safety of the worker.

416 Advanced Mineral Engineering Design II (Lect 1.0 and Lab 2.0) Incorporation of principles developed in Mining 415 in advanced design projects for mineral plants and systems, with emphasis on environmental protection, health, and safety. Prerequisite: Mi Eng 415.

432 Advanced Rock Mechanics (Lect 3.0 Advanced topics in static and dynamic rock mechanics; elasticity theory, failure theories and fracture mechanics applied to rock; stress wave propagation and dynamic elastic constants; rock mass classification methods for support design; pillar design in coal and metal mines; introduction to numerical models. Prerequisite: Mi Eng 231 or Cv Eng 215.

433 Rock Mechanics IV (Lect 3.0) Advanced topics in dynamic rock mechanics. Stress ware propagation in the earth, dynamic elastic constants in isotropic and anisotropic rock, Hopkinson bar impact analysis, spallation and radial fracturing caused by stress pulses, shock ware generation in rock by explosives, shock ware propagation and effects. Prerequisite: Mi Eng 231 or Cv Eng 215.

434 Mining Law (Lect 3.0) Federal and state mining statutes including regulations governing lode and placer claims, leases, environmental protection, safety, and taxation.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

491 Internship (Variable) Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

NUCLEAR ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course. Variable title.

303 Reactor Physics I (Lect 3.0) Study of neutron interactions, fission, chain reactions, neutron diffusion and neutron slowing down; criticality of a bare thermal homogeneous reactor. Prerequisites: Math 204 and Nu Eng 203 or Physics 107.

304 Reactor Laboratory I (Lect 1.0 and Lab 1.0) Acquaints the student with neutron flux measurement, reactor operation, control rod calibration, reactor power measurement and neutron activation experiments. Experiments with the thermal column and neutron beam port are also demonstrated. Prerequisites: English 160, Nu Eng 204 and 205.

306 Reactor Operation (Lab 1.0) The operation of the training reactor. The program is similar to that required for a NRC license. Prerequisite: Nu Eng 205.

307 Nuclear Fuel Cycle (Lect 3.0) Nuclear fuel reserves and resources; milling, conversion, and enrichment; fuel fabrication; in-and-out-of core fuel management; transportation, storage, and disposal of nuclear fuel; low level and high level waste management, economics of the nuclear fuel cycle. Prerequisite: Nu Eng 205.

308 Reactor Laboratory II (Lect 1.0 and Lab 1.0) A continuation of Nuclear Engineering 304 with experiments of a more advanced nature. Prerequisite: Nu Eng 304.

309 Licensing of Nuclear Power Plants (Lect 2.0) The pertinent sections of the Code of Federal Regulations, the Nuclear Regulatory Commission's Regulatory Guides and Staff Position Papers, and other regulatory requirements are reviewed. Safety analysis reports and environmental reports for specific plants are studied.

310 Seminar (Variable) Discussion of current topics. Prerequisite: Senior standing.

311 Reactor Physics II (Lect 3.0) Analytic and computer based methods of solving problems of reactor physics. Prerequisites: Nu Eng 303, Cmp Sc 228.

315 Space Nuclear Power and Propulsio (Lect 3.0) A study of the design, operation and application of radioisotope power generators and nuclear reactors for space power and propulsion systems used on both manned and unmanned missions. Prerequisite: Math 204.

321 Nuclear Power Plant Design (Lect 3.0) A study of current nuclear power plant concepts and the environmental economics and safety considerations affecting their design. Includes such topics as: thermal, mechanical and electrical aspects of nuclear power facilities, and the nuclear fuel cycle. Prerequisites: Nu Eng 205 and Mc Eng 219.

323 Nuclear System Design (Lect 3.0) A complete design of a nuclear system (e.g.a fission or fusion nuclear reactor plant, a space power system, a radioactive waste disposal system). Prerequisites: Nu Eng 311, 321.

333 Health Physics (Lect 2.0) Radiation sources, dose calculations, dose units, biological effects of radiation, federal and state regulations regarding radiation, proper use of radioisotopes, operation and use of health physics instruments and dosimeters. Prerequisite: Nu Eng 203 or Physics 107.

335 Radiation Protection Engineering (Lect 3.0) The stopping of charged particles, photons, and neutrons by matter. Sources of radiation (nuclear reactors, radioactive wastes, x-ray machines, and accelerators). Biological effects of radiation. Radiation protection guides. Radiation shield design. Prerequisite: Nu Eng 205.

341 Nuclear Materials I (Lect 3.0) Fundamentals of materials selection for components in nuclear applications, design and fabrication of UO2 fuel; reactor fuel element performance; mechanical properties of UO2; radiation damage and effects, including computer modeling; corrosion of materials in nuclear reactor systems. Prerequisites: Nu Eng 205, Mt Eng 121. (Co-listed with Mt Eng 341)

345 Radioactive Waste Management and Remediation (Lect 3.0) Sources and classes of radioactive waste, long-term decay, spent fuel storage, transport, disposal options, regulatory control, materials issues, site selection and geologic characterization, containment, design and monitoring requirements, domestic and foreign waste disposal programs, economic and environmental issues, history of disposal actions, and conduct of remedial actions and clean up. Prerequisite: Math 204. (Co-listed with Geo 345)

351 Reactor Kinetics (Lect 3.0) Derivation and solutions to elementary kinetics models. Application of the point kinetics model in fast, thermal reactor dynamics, internal and external feedback mechanism. Rigorous derivation and solutions of the space dependent kinetics model fission product and fuel isotope changes during reactor operation. Prerequisite: Nu Eng 205.

361 Fusion Fundamentals (Lect 3.0) Introduction to the plasma state, single particle motion, kinetic theory, plasma waves, fusion, power generation, radiation mechanisms, inertial confinement and fusion devices, including conceptual fusion power plant designs. Prerequisite: Preceded or accompanied by Math 204.

381 Probabilistic Risk Assessment I (Lect 3.0) A study of the techniques for qualitative and quantitative assessment of reliability, safety and risk associated with complex systems such as those encountered in the nuclear power industry. Emphasis is placed on fault tree analysis. Prerequisite: Nu Eng 205.

390 Undergraduate Research (Variable) Designed for the undergraduate student who wishes to engage in research. Not for graduate credit. Not more than six credit hours allowed for graduation credit. Subject and credit to be arranged with the instructor.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

405 Linear Transport Theory (Lect 3.0) Monoenergetic Boltzmann equation for neutral particles by the method of singular eigen-functions and polynomial expansions. Prerequisites: Nu Eng 303, Math 358.

410 Seminar (Variable) Discussion of current topics.

411 Computational Methods in Nuclear Engineering (Lect 3.0) Numerical solution of the neutron diffusion and transport equations utilizing the computer. The Sn and Pn methods are studied in detail. Prerequisites: Nu Eng 305 and Cmp Sc 218.

421 Advanced Nuclear Reactor Design (Lect 3.0) Complete design of a nuclear power reactor, including analysis of reactor physics and engineering; layout and design of primary and secondary cooling systems, pressure vessel and thermal shields, control systems; introduction to the economics of nuclear power. Prerequisites: Nu Eng 311 and 321.

423 Nuclear Reactor Safety (Lect 3.0) Study of safety criteria; reactor characteristics pertinent to safety; reactor transient behavior; loss of coolant accident analysis; emergency core cooling; fuel behavior during accident conditions; reactor risk analysis; current reactor safety issues. Prerequisites: Nu Eng 303 and 321.

425 Plasma Physics (Lect 3.0) Fundamentals of kinetic, theory, fluid equations, MHD equations, and applications: wave propagation, shielding effect, diffusion, stability, and charged particle trajectories. Prerequisite: Nu Eng 361 for Nu Eng; Physics 411 for Physics.

431 Radiation Shielding (Lect 3.0) Radiation sources; interactions of radiation with matter; dosimetry and radiation protection guidelines. The particle transport equation and methods of

solving it; the Monte Carlo Method; special computational methods for neutron and gamma attentuation. Computer codes used in shielding. Shielding materials, shield design. Prerequisite: Nu Eng 303.

441 Effects of Radiation on Solids (Lect 3.0) The theories of the interaction of nuclear radiation with matter. Experimental approaches to radiation studies, including the sources and dosimetry. Nature and properties of crystal imperfections. The influence of radiation on physical, mechanical and surface properties of metals and alloys. Radiation effects on materials other than those incorporated in nuclear reactors. The annealing of defects. Prerequisite: Mt Eng 341.

481 Probabilistic Risk Assessment II (Lect 3.0) A continuation of Nu Eng 381 with emphasis on reliability, importance, availability and frequency of occurrence. Advanced topics of phased mission analysis and dynamic fault tree analysis will be considered. The use of fault tree results with respect to risk calculations will be studied. Prerequisite: Nu Eng 381.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

491 Internship (Variable) Students working toward a doctor of engineering degree will select with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

PETROLEUM ENGINEERING

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the deparment. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

302 Offshore Petroleum Technology (Lect 3.0) An introduction to both the practical and theoretical aspects of development of offshore oil fields. Practical problems include current drilling and workover procedures, oil storage methods, and oil transportation problems. Theoretical topics which are introduced include the prediction of wind, wave, and current forces. Prerequisite: Pe Eng 131.

303 Environmental Petroleum Applications (Lect 3.0) This course is a study of environmental protection and regulatory compliance in the oil and gas industry. The impact of various environmental laws on drilling and production operations will be covered. Oilfield and related wastes and their handling are described. Federal, state and local regulatory agencies are introduced, and their role in permitting and compliance monitoring is presented. Legal and ethical responsibilities are discussed. Prerequisite: Senior standing.

308 Applied Reservoir Simulation (Lect 3.0) Simulation of actual reservoir problems using both field and individual well models to determine well spacing, secondary recovery prospects, future rate predictions and recovery, coning effects, relative permeability adjustments and other history matching techniques. Co-requisite: Pe Eng 257.

310 Seminar (Lect 1.0) Discussion of current topics. (Course cannot be used for graduate credit). Prerequisite: Senior standing in Pe Eng.

314 Advanced Drilling Technology (Lect 3.0) In-depth studies of cost control; hole problems; well planning; drilling fluids and cuttings transport; hydraulics; pressure control, directional drilling; drill bits; cementing; fishing; wellhead and tubular designs; computer modeling of drilling systems optimized design of drilling procedure. Prerequisites: Pe Eng 131, Cv Eng 230, Cmp Sc 73.

316 Production Applications (Lect 2.0 and Lab 1.0) An introduction to production engineering topics: single and multi-phase flow through pipes; inflow performance; nodal systems analysis; perforating; acidizing; hydraulic fracturing; well completion equipment and practices; production logging; well servicing. Prerequisites: Cv Eng 230, Pe Eng 131, preceded or accompanied by Pe Eng 241.

320 Fundamentals of Petroleum Reservoir Simulation (Lect 3.0) An introduction to petroleum reservoir simulation. Fundamentals of finite difference approximation of the partial differential equations of flow through porous media. Discussion of various simulation schemes, data handling, boundary conditions. Use of a dry gas and black oil simulators. Prerequisites: Cmp Sc 73, Math 204.

323 Artificial Lift (Lect 3.0) This course is a study of artificial lift methods used to produce liquids (oil/water) from wellbores. Methods covered include sucker rod (piston) pumps, electric submersible pumps, gas lift, hydraulic lift and plunger lift. Prerequisite: Pe Eng 241 or equivalent.

329 Applied Petroleum Reservoir Engineering (Lect 3.0) Quantitative study of oil production by natural forces, gas cap, water influx, solution gas,

etc.; material balance equations, study of gas, non-retrograde gas condensate, and black oil reservoirs. Predictive calculations of oil recovery from different reservoir types. Prerequisites: Pe Eng 241 and 242.

333 Reservoir Characterization (Lect 3.0) The integration and extrapolation of Geologic, Geophysical, and Petroleum Engineering data for flow model construction.

335 Secondary Recovery of Petroleum (Lect 3.0) Oil recovery by water or gas injection. Various prediction methods. Design of water flooding projects. Cyclic steam stimulation of oil wells, design criteria. Oil recovery from thermally stimulated wells, prediction methods. Brief-introduction to EOR (enhanced oil recovery) methods. Prerequisites: Pe Eng 241, 242, and Mc Eng 227.

341 Well Test Analysis (Lect 2.0 and Lab 1.0) Causes of low well productivity; analysis of pressure buildup tests, drawdown tests, multi-rate tests, injection well fall off tests, and open flow potential tests; design of well testing procedures. Prerequisites: Pe Eng 241 and Math 204.

347 Petroleum Engineering Design (Lect 2.0 and Lab 1.0) The application of engineering principles in the design, selection, and installation of oil field equipment. Prerequisites: Pe Eng 241, 316, Bas En 110.

360 Natural Gas Engineering (Lect 3.0) Gas reserves estimation, deliverability, and future production performance prediction. Deliverability testing of gas wells including isochronal, flow after flow, drawdown and buildup. Gasfield development and underground storage. Gas production metering gauging and transmission. Prerequisite: Preceded or accompanied by Pe Eng 241.

400 Special Problems (Variable) Problems or readings on specific subjects of projects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

406 Advanced Reservoir Simulation (Lect 3.0) Advanced techniques in reservoir simulation. Prerequisite: Pe Eng 308.

410 Seminar (Variable) Discussion of current topics.

417 A Survey of Improved Recovery Processes (Lect 3.0) An overview of current advanced recovery methods including secondary and tertiary processes. An explanation of the primary energy mechanism and requirements of these methods and an analysis of laboratory results and their subsequent field applications. Prerequisite: Pe Eng 335.

437 Advanced Reservoir Engineering I (Lect 3.0) Advanced study of producing mechanisms. Prerequisites: Pe Eng 308 and Pe Eng 341.

438 Advanced Reservoir Engineering II (Lect 3.0) Flow through porous media: derivations and solutions for steady, semi-steady, and transient flow of single and multiple phase flow through porous media. Prerequisite: Pe Eng 241.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

491 Internship (Variable) Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

PHYSICS

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

302 Physics for Elementary School Teachers (Lect 2.0 and Lab 1.0) A nonmathematical review of the fundamental ideas of physics, including mechanics, matter, energy, sound, electricity, magnetism, astronomy, and light. Emphasis is placed on the development of hands-on activities. (For elementary school teachers or Master of Science for Teachers candidates only.)

305 Astrophysics (Lect 3.0) The structure, physical characteristics and evolution of stars, binary systems, nebulae and galaxies. Prerequisite: Physics 107.

307 Modern Physics II (Lect 3.0) A continuation of Physics 207. An introduction to nuclear and particle physics. Topics include nuclear models, decays, and reactions, and elementary particles and fundamental forces. Prerequisites: Math 204 or 229, and either Physics 107 with consent of instructor or Physics 207.

308 Physical Mechanics (Lect 3.0) This course covers topics of rigid body motion in three dimensions, moving coordinate frames, two body collisions, conservation laws, small oscillations,

generalized coordinates, and LaGrange's and Hamilton's equations. Prerequisite: Physics 208.

311 Thermal Physics (Lect 3.0) A study of the equilibrium states of matter as governed by the first and second laws of thermodynamics. Emphasis is placed on the microscopic approach with an introduction to statistical mechanics. Topics include the kinetic theory of (uniform) gases, phase equilibria in pure systems, and an introduction to quantum statistics. Prerequisite: Physics 107 or 207.

313 Introduction to General Relativity (Lect 3.0) An introduction to the theory of general relativity. Topics covered include the formalism of general relativity, Einstein's gravitational field equations, the Schwarzschild solution, black holes, and cosmological models of the universe. Prerequisite: Physics 208.

321 Electricity and Magnetism II (Lect 3.0) A continuation of Physics 221. Topics covered include the magnetostatic field, the magnetic vector potential, the magnetostatic field in matter, electrodynamics, and electromagnetic waves. Prerequisite: Physics 221.

322 Advanced Physics Laboratory I (Lab 3.0) A laboratory study of the principles of basic experiments in all major branches of physics. The experiments stress design of apparatus, and procedures and analysis in projects involving electronic, optical, mechanical, and vacuum techniques. Prerequisite: Physics 212.

323 Classical Optics (Lect 3.0) Physical optics and advanced topics in geometrical optics. Topics include ray propagation, electromagnetic propagation, mirrors, lenses, interference, diffraction, polarization, imaging systems, and guided waves. Prerequisites: Math 22 and Physics 24 or 25. (Co-listed with El Eng 323)

324 Fourier Optics (Lect 3.0) Applications of Fourier analysis and linear system theory to optics. Topics include scalar diffraction theory, Fouriertransforming properties of lenses, optical information processing, and imaging systems. Prerequisites: El Eng 261 & 275 or Physics 208 & 321. (Co-listed with El Eng 324)

326 Fiber and Integrated Optics (Lect 3.0) Introduction to optical waveguides and their applications to communication and sensing. Topics include dielectric waveguide theory, optical fiber characteristics, integrated optic circuits, coupled-mode theory, optical communication systems, and photonic sensors. Prerequisite: El Eng 275 or Physics 321. (Co-listed with El Eng 326)

332 Advanced Physics Laboratory II (Lab 3.0) A senior laboratory involving experimental design. The student must specify his objectives, assemble apparatus, take measurements, analyze the results, form conclusions, write a report, and deliver an oral presentation of the results. Prerequisite: Physics 212.

337 Atmospheric Science (Lect 3.0) An introductory survey designed to acquaint engineering and science students with the fundamentals of Atmospheric Science. Topics include atmospheric thermodynamics, synoptic scale disturbances, atmospheric aerosols (including cloud and precipitation physics), atmospheric electricity, and radiative transfer. Prerequisities: Mc Eng 221 or 227, Ch Eng 141, or Chem 241, or Physics 311. (Co-listed with Mc Eng 337)

341 Contemporary Optics (Lect 3.0) Basic optics techniques required in research or optical communication. Topics covered are basic geometric optics, commercial lens design programs, semiconductor lasers and LED's, modulation, optical detectors, fiber optics, optical communication systems, and other topics of interest. Prerequisite: Physics 24.

345 Acoustics (Lect 3.0) Theory of oscillating mechanical systems, wave propagation, the production and transmission of sound, and ultrasonics. Prerequisites: Math 22 and Physics 24 or 25.

357 Subatomic Physics (Lect 3.0) An introduction to elementary particles. Topics include particle properties, nuclear forces, particle interactions, the Standard Model for quarks and leptons, fundamental forces in gauge field theory models, and the role of elementary particle interactions in cosmology. Prerequisite: Physics 307.

361 Introduction to Quantum Mechanics (Lect 3.0) The fundamental concepts, postulates and methods of quantum mechanics and their applications to physical systems. Topics include solutions of the Schrodinger equation for simple systems and operator methods. Prerequisites: Physics 107 or 207, 208.

367 Plasma Physics (Lect 3.0) Single-particle motions, plasmas as fluids, waves, diffusion, equilibrium, stability, kinetic theory, nonlinear effects Prerequisites: Math 204 and Physics 107 or 207 or Nu Eng 203.

371 Quantum Electronics (Lect 3.0) The generation of coherent radiation by lasers and the interaction of laser radiation with matter. Topics include stimulated emission, population inversion, optical cavities, optical gain, properties of laser media and other applications. Prerequisite: Physics 107 or 207.

377 Principles of Engineering Materials (Lect 3.0) Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Ae Eng 377, Ch Eng 377, Mt Eng 377, Cr Eng 377)

381 Elementary Solid State Physics (Lect 3.0) An introductory study of the structure and physical Properties of crystalline solids. Included are topics in crystal structure, x-ray diffraction, crystal binding, thermal properties of solids, free electron theory and elementary energy band theory. Prerequisites: Math 204 and Physics 107 or 207.

390 Undergraduate Research (Variable) This course is designed for the undergraduate student who wishes to engage in research. It is not to be used for graduate credit nor for more than six credit hours of undergraduate credit. The subject and credit are to be arranged with the instructor.

400 Special Problems (Variable) Problems or readings on specific subjects or projects in the department Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

409 Classical Mechanics I (Lect 3.0) Methods of Newton, Lagrange, and Hamilton applied to the motion of particles and rigid bodies. Introduction to canonical transformations and Poisson brackets. Classical scattering and small oscillations. Prerequisites: Math 204, Physics 309.

410 Seminar (Variable) Discussion of current topics.

411 Electrodynamics I (Lect 3.0) A rigorous development of the fundamentals of electromagnetic fields and waves. Electrostatics, magnetostatics, Maxwell's equations—Green's function, boundary value problems, multipoles, conservation laws. Prerequisites: El Eng 273 and Math 325; Physics 321.

413 Statistical Mechanics (Lect 3.0) A study of statistical ensembles; Maxwell-Boltzmann, FermiDirac and Einstein-Bose distribution laws, application to some simple physical systems. Prerequisites: Physics 309, 361.

423 Electrodynamics II (Lect 3.0) A continuation of Physics 411. Applications of time-dependent Maxwell's equations to such topics as plasmas, wave guides, cavities, radiation; fields of simple systems and multipoles. Relativity; covariant formulation of Maxwell's equations and conservation laws, fields of uniformly moving and accelerated charges. Prerequisite: Physics 411.

435 Cloud Physics (Lect 3.0) A study of cloud microphysics and dynamics: atmospheric condensation and freezing, nuclei, nucleation, development of liquid or ice phase, percipitation mechanisms, aerosal scavenging, role of electrification, current dynamical models, and review of diagnostic techniques. Prerequisites: Physics 107, Chem 373, Math 325.

455 Theoretical Nuclear Physics (Lect 3.0)Structure of simple nuclei, basic properties of nuclei, shell model, liquid drop model, range-energy correlations, fission, fusion, radioactivity, nuclear interactions and scattering cross sections, electroweak interactions, and introduction to quark model and its applications. Prerequisite: Physics 461.

461 Quantum Mechanics I (Lect 3.0) Basic formalism applied to selected problems. Schroedinger equation and one dimensional problems, Dirac notation, matrix mechanics, harmonic oscillator, angular momentum, hydrogen atom, variational methods, introduction to spin. Prerequisite: Physics 361 or equivalent.

463 Quantum Mechanics II (Lect 3.0) Perturbation theory, treatment of spin, angular momentum addition, Wigner-Eckart theorem; scattering theory including partial wave analysis, born approximation, and formal scattering theory; identical particles, introduction to second quantization, and structure of complex atoms. Prerequisite: Physics 461.

467 Quantum Statistical Mechanics (Lect 3.0) Techniques for calculation of the partition function with examples drawn from interacting Fermi gas, interacting Bose gas, superconductors, and similar sources. Prerequisites: Physics 413 and 463.

471 Atomic and Molecular Structure (Lect 3.0) Applications of quantum mechanics to the structure of atoms and molecules; perturbation and variational calculations, self-consistent field, multiplets, angular momenta, Thomas-Fermi model, diatomic molecules, spectral intensities. Prerequisite: Physics 461.

473 Atomic Collisions (Lect 3.0) Basic quantum mechanical concepts involved in atomic scattering theory. Topics include the Born approximation elastic collisions, and inelastic collisions. Other specific topics will be chosen from the general areas of electron, ion, and atom collisions with atoms and molecules. Prerequisite: Physics 471 or 463.

481 Physics of the Solid State (Lect 3.0) Crystal symmetry, point and space groups, lattice vibrations, phonons, one-electron model, Hartree-Fock approximation, elementary energy band theory, transport properties, the Boltzmann equation, introduction to superconductivity, semi-conductors, and magnetism. Prerequisite: Physics 461.

483 Selected Topics of the Solid State (Lect 3.0) Introduction to many-body perturbation theory, the use of Feynman's diagrams, Green's functions, treatment of the electron-electron, phonon-phonon, and electron-phonon interactions, theory of magnetism and theory of superconductivity. Prerequisite: Physics 481.

485 Advanced Quantum Mechanics (Lect 3.0) Selected Topics such as many-body problems, field theory, S matrix theory and symmetries. Prerequisite: Physics 465.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

494 Coop Registration (1 Hour)

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so

may invalidate the candidacy. Billing will be automatic as will registration upon payment.

STATISTICS

300 Special Problems (Variable) Problems or readings on specific subjects or projects in the department. Consent of instructor required.

301 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

305 Making Sense of Data for Elementary School Teachers (Lect 3.0) An activity based course that is intended to provide elementary school teachers with the skills necessary to implement the Probability & Statistics strand of the American Statistical Association of the National Council of Teachers of Mathematics (NCTM) joint. Prerequisite: Graduate Standing.

306 Making Sense of Data for Middle School Teachers (Lect 3.0) An activity based course that is intended to provide middle school teachers with the skills necessary to implement the Probability & Statistics strand of the American Statistical Association of the National Council of Teachers of Mathematics (NCTM) joint.

307 Making Sense of Data for High School Teachers (Lect 3.0) An activity based course that is intended to provide high school teachers with the skills necessary to implement the Probability & Statistics strand of the American Statistical Association of the National Council of Teachers of Mathematics (NCTM) joint.

320 Statistical Methods (Lect 3.0) A continuation of Stat 215 with emphasis on statistical methods. Topics would include further work on regression analysis, control charts, acceptance sampling, nonparametric statistics, goodness of fit tests, reliability and life-testing, analysis of experimental designs. Prerequisite: Stat 215.

343 Probability and Statistics (Lect 3.0) Intorduction to the theory of probability and its applications, sample spaces, random variables, binomial, Poisson, normal distributions, derived distributions, and moment generating functions. Prerequisite: Math 22.

344 Mathematical Statistics (Lect 3.0) A continuation of Stat 343 with introduction to the theories of point estimation, hypothesis testing, and interval estimation. Includes sufficiency, completeness, likelihood and how they apply to the exponential family. Prerequisite: Stat 343.

346 Regression Analysis (Lect 3.0) Simple linear regression, multiple regression, regression diagnostics, multicollinearity, measures of influence and leverage, model selection techniques, polynomial models, regression with autocorrelated errors, introduction to non-linear regression. Prerequisites: Math 22 and one of Stat 211, 213, 215, 217, or 343. (Co-listed with Cmp Sc 366)

353 Statistical Data Analysis (Lect 3.0) Introduction to methods for analyzing statistical data from experiments and surveys. Analysis of variance, correlation, introduction to regression techniques, contingency tables, non-parametric techniques and introduction to modern statistical software. Prerequisites: Math 22 and one of Stat 115, 213, 215 and 217.

390 Undergraduate Research (Variable) This course is designed for the undergraduate student who wishes to engage in research. It is not to be used for graduate credit nor for more than six credit hours of undergraduate credit. The subject and credit are to be arranged with the instructor. Prerequisite: Consent of instructor.

400 Special Problems (Variable) Problems or readings on specific subjects in the department. Consent of instructor required.

401 Special Topics (Variable) This course is designed to give the department an opportunity to test a new course.

414 Statistical Time Series Analysis (Lect 3.0) A formal introduction to the fundamentals of statistical modeling and analysis of discrete time series. Topics include autoregressive and moving average processes, ARMA models, second order stationarity, vector processes, autocorrelation function, Fourier representation, estimation and prediction of time series. Prerequisites: Stat 343 and Math 203 or 208.

438 Industrial Queueing Theory (Lect 3.0)Mathematical methods for modeling and analysis of queueing systems using probability theory. Topics include: counting processes, discrete-time processes, single and multiple server queues and Markovian queueing processes. Prerequisites: Eng Mg 382, Stat 213 or equivalent. (Co-listed with Eng Mg 438)

441 Stochastic Processes (Lect 3.0) Development and application of Poisson and nonhomogeneous Poisson processes; renewal processes; Markov chains and processes including birth and death processes; and normal processes, including Brownian motion. Prerequisites: Stat 343 and Math 204 or 229.

443 Nonparametric Statistical Methods (Lect 3.0) A course covering distribution free statistical methods. Topics include: order statistics, tests of hypotheses for one-sample and two-sample problems, analyses of variance, goodness-of-fit tests, runs test, independence and regression problems, point and interval estimation, ARE. Prerequisite: Stat 344.

444 Design and Analysis of Experiments (Lect 3.0) Experimental designs and their statistical analysis. Includes completely randomized designs, complete and incomplete blocking designs, factorial and fractional factorial experiments, multiple comparisons, response surface analysis. Prerequisites: One of Stat 343, 353 or Eng Mg 387; and one of Stat 211, 213, 215 or 217.

445 Multivariate Statistical Methods (Lect 3.0) Analysis of data consisting of simultaneous measurements on many variables. Multivariate normal

distribution, multivariate analysis of variance, canonical correlation, principal components, classification and clustering techniques. Prerequisites: Stat 344 and Math 203.

446 Intermediate Probability (Lect 3.0) Probability spaces, random variables, distribution functions, expectations, independence, convergence theorems, characteristic functions, moment generating functions, and central limit theorem. Prerequisites: Stat 344 and Math 315.

453 Linear Statistical Models I (Lect 3.0) Includes a development of the theory of the distribution of quadratic forms, and the estimation of parameters and testing hypotheses in linear statistical models. Prerequisites: Math 208 and Stat 343 and either Stat 353 or 344.

454 Linear Statistical Models II (Lect 3.0) Includes the theory of polynomial models, regression models, experimental design models, incomplete block models, nonlinear models, with emphasis on optimum properties of point and interval estimation and the power of tests. Prerequisite: Stat 453.

457 Advanced Mathematical Statistics I (Lect 3.0) The theory of estimation and hypothesis testing. Completeness and sufficience. Maximum likelihood, minimax, Bayesian and invariant procedures for testing. Sequential desision rules. Emphasis on estimation. Prerequisites: Stat 344 and Math 315.

458 Advanced Mathematical Statistics II (Lect 3.0) A continuation of Stat 457 with the emphasis on hypothesis testing. Prerequisite: Stat 457.

470 Theory of Reliability (Lect 3.0) Statistical analysis of life-testing distributions such as the Weibull, gamma, exponential, logistic, and normal. Reliability estimation, tolerance limits, censored sampling, and applications of Monte-Carlo simulation. Prerequisite: Stat 344.

490 Research (Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

493 Oral Examination (0.0 Hours) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

495 Continuous Registration (Lect 1.0) Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.