GRADUATE-LEVEL ENGINEERING COURSE DESCRIPTIONS

Not all of the engineering courses listed below are offered each year. Students should check the University's schedule of classes or inquire at the ECE and MME Engineering Departments (303-871-2102) to determine which classes are offered in a given academic year.

BIOENGINEERING

ENBI 3800 Special Topics (Bioengineering) (1-5 qtr. hrs.)
Various topics in bioengineering as announced. May be taken more than once. Prerequisite: varies with offering.

ENBI 4500 Biofluids (4 qtr. hrs.)
The application of fluid dynamics theory and design to problems within the biomedical community. Specific topics covered will include the mechanics of inhaled therapeutic aerosols, basic theory of circulation and blood flow, foundations in biotechnology and bioprocessing, and controlled drug delivery.

ENBI 4510 Biomechanics (4 qtr. hrs.)
An introduction to the mechanical behavior of biological tissues and systems. Specific topics covered will include: Analysis of the human musculoskeletal system as sensors, levers, and actuators, Joint articulations and their mechanical equivalents, Kinematic and kinetic analysis of human motion, Introduction to modeling human body segments and active muscle loading for analysis of dynamic activities, Mechanical properties of hard and soft tissues, Mechanical and biological consideration for repair and replacement of soft and hard tissue and joints, Orthopedic implants. [prerequisites ENME 2410, ENME 2510]

ENBI 4800 Adv Topics (Bioengineering) (1-5 qtr. hrs.)
Various topics in bioengineering as announced. May be taken more than once. Prerequisite: varies with offering.

ENBI 4991 Independent Study (1-10 qtr. hrs.)

ENBI 4995 Independent Research (1-18 qtr. hrs.)

COMPUTER ENGINEERING

ENCE 3100 Advanced Digital Systems Design (4 qtr. hrs.)
Design of logic machines. Finite state machines, gate array designs, ALU and control unit designs, microprogrammed systems. Hardware design of digital circuits using SSI and MSI chips. Introduction to probability and statistics. Application of probability and stochastic processes for cache and paging performance. Laboratories incorporate specification, top-down design, modeling, implementation and testing of actual digital design systems hardware. Simulation of circuits using VHDL before actual hardware implementation. Laboratory.

ENCE 3210, 3220 Microprocessor Systems I, II
(4 qtr. hrs. each)
Introduction to microprocessors and to the design and operation of computer systems. A study of the microprocessor and its basic support components. Analysis of CPU architectures of modern computers. Assembly language programming. Use of an assembler and other development tools for programming and developing microprocessor-based systems. Laboratory.

ENCE 3225 Digital and Microprocessor Sys (4 qtr. hrs.)
An intensive course designed to familiarize students with the basic concepts of digital design and microprocessor systems, and to prepare them to pursue advanced courses in these areas. Topics include number systems, digital logic design and computer architecture. It includes a laboratory for hands-on experience with digital systems design and programming a microcontroller. This course is for non-computer and electrical engineering majors.

ENCE 3231 Embedded Microprocessor Systems
(4 qtr. hrs.)
Design, construction and testing of microprocessor systems. Hardware limitations of the single-chip system. Includes micro-controllers, programming for small systems, interfacing, communications, validating hardware and software, microprogramming of controller chips, design methods and testing of embedded systems. Project.

ENCE 3241 Computer Organization (3 qtr. hrs.)
Organization of digital computers. Memory, register transfer and datapath. Arithmetic Logic Unit. Computer architecture. Control unit. I/0 systems. Prerequisite: ENCE 2101.

ENCE 3250 HDL Modeling and Synthesis (3 qtr. hrs.)
Introduction to Hardware Design Language (HDL). Language syntax and synthesis. Applications related to digital-system implementation are developed. Project.

ENCE 3321 Network Design (3 qtr. hrs.)
Introduction to network components. Layering of network architecture. Analysis of Local Area Network (LAN) concepts and architecture based on IEEE standards. Design principles including switching and multiplexing techniques, physical link, signal propagation, synchronization, framing and error control. Application of probability and statistics in error detecting and control. Ethernet, Taken-ring, FDDI (Fiber Distributed Data Interface), ATM (Asynchronous Transfer Made), ISDN (Integrated Service Data Networks).

ENCE 3501 VLSI Design (3 qtr. hrs.)
Design of Very Large Scale Integration integrated systems. Examination of layout and simulation of digital VLSI circuits using a comprehensive set of CAD tools in a laboratory setting. Studies layouts of CIVICS combinational and sequential circuits using automatic layout generators. Fundamental structures of the layout of registers, adders, decoders, ROM, PLA's, counters, RAM and ALU. Application of statistics and probability to chip performance. CAD tools allow logic verification and timing simulation of the circuits designed.

ENCE 3830 Special Topics (CPE) (1-5 qtr. hrs.)
Special topics in computer engineering as announced. May betaken more than once. Prerequisite: varies with offering.

GRADUATE-LEVEL ENGINEERING COURSE DESCRIPTIONS

ENCE 4100 High-Speed Digital Design (3 qtr. hrs.)
Fundamental topics related to the development of high-speed digital systems. Topics include signal integrity and reliability related to crosstalk, parasitics- and electromagnetic interference caused by device clocking speed and system complexity. Project.

ENCE 4231 Embedded Systems Programming(4 qtr. hrs.)
Design, construction and testing of microprocessor systems. Hardware limitations of the single-chip system. Includes micro-controllers, programming for small systems, interfacing, communications, validating hardware and software, microprogramming of controller chips, design methods and testing of embedded systems. Project.

ENCE 4300 Mixed Signal Design and Testing (3 qtr. hrs.)
Design, analysis and implementation of testable mixed-signal systems. The test specification process and design for test (DDT) techniques. Digital, analog and DSP-based testing. Measurement accuracy and data analysis. Use of simulation tools to design and verify systems. Prerequisites: ENEE 2011, ENEE 3111 and ENCE 2101, or permission of instructor.

ENCE 4341 Distributed Systems (3 qtr. hrs.)
Fundamentals of distributed systems, distributed computing models, distributed file and directory services, distributed systems hardware and software design and implementation issues, reliability and availability, and fault tolerance are covered. Project.

ENCE 4421 Robot Computer Vision (3 qtr. hrs.)
Fundamental techniques for computer vision applied to robotics. Examines image formation, filtering, processing, boundary detection, image segmentation, texture analysis, shape from shading, object modeling, stereo vision, motion, and optical flow, shape description, and object recognition (classification). Topics in sensor design, physics and geometry for perception, and perception systems. Project.

ENCE 4501 Advance VLSI Design (3. qtr. hrs.)
Advanced techniques in the fabrication and design of VLSI circuits and systems. Modeling of parasitic components. Floor-planning, clock distribution, routing, and low-power design.

ENCE 4800 Advanced Topics (CPE) (1-5 qtr. hrs.)
Various topics in computer engineering as announced. May be taken more than once.

ENCE 4991 Independent Study (1-10 qtr. hrs.)

ENCE 4995 Independent Research (1-18 qtr. hrs.)

ELECTRICAL ENGINEERING

ENEE 3011 Physical Electronics (4 qtr. hrs.)
The basic physical concepts of electronics, electrons and holes in semiconductors, transport and optical processes. Concentration on device concepts, including material synthesis and device processing, P-N junction diodes, junctions with other materials, bipolar transistors, field effect transistors (JFET, MESFET, MOSFET) and optoelectronics devices (lasers, detectors).

ENEE 3030 Optoelectronics (4 qtr. hrs.)
The active and passive optical elements: includes principles of light, optical sources (LED, LASER, Fiber LASER), optical fibers, photo detectors (APD, PIN, MSM) and practical optical transmitters and receivers. Laboratory.

ENEE 3035 Photonics (4 qtr. hrs.)
Theory and techniques for the application of the optical electromagnetic spectrum from infrared to ultraviolet to engineering problems in communications, instrumentation and measurement. May include lasers, optical signal processing, holography, nonlinear optics, optical fiber communications, optical behavior of semiconductors and similar topics in modern optics, depending on the interests and requirements of the students.

ENEE 3111 Signals and Systems (4 qtr. hrs.)
Introduces continuous-time and discrete-time linear system analysis, Fourier series, Fourier and Laplace transforms. Specific engineering tools for discrete time linear system analysis include discrete time convolution, Z-transform techniques, discrete Fourier transform and fast Fourier transform (DFT/FFT), and the design and analysis of analog and digital filters for real-world signal processing applications.

ENEE 3130 Principles of Communication Systems
(3 qtr. hrs.)
Introduction to the theory and analysis of communication systems. Emphasis on analog systems; application of probability and statistics, modulations and demodulations; noise and signal-to-noise ratio analysis; the measure of information, channel capacity, coding and design factors.

ENEE 3141 Digital Communications (4 qtr. hrs.)
Introductory course on modem digital communication systems. The basic communication system theory, probability theory, random process theory, baseband digital data transmission, coherent modulation analysis to predict theoretical error probabilities, and noncoherent digital modulation techniques. Bandwidth efficiency and transmission of digital data through band-limited channels.

ENEE 3150 Communication Systems Lab (4 qtr. hrs.)
Communication systems experiments demonstrating classical and applied features of digital and analog communication principles. Includes digital and analog modulation techniques. A consolidated laboratory experience for students in the communication sequence with a capstone design of a complete communications process, including source coding, channel coding, transmission over media, reception and decoding, followed by a detailed performance analysis of the reliability of the sequence of processes.

ENEE 3611 Antennas and Antenna Arrays (4 qtr. hrs.)
Maxwell's equations applied to antenna analysis and design. Topics include fundamental parameters of antennas, radiation integrals and auxiliary potential functions, analysis and design of linear wire antennas, loop antennas, arrays, broadband antennas, frequency independent antennas, aperture antennas and horns.

GRADUATE-LEVEL ENGINEERING COURSE DESCRIPTIONS

ENEE 3620 Optical Fiber Communications (4 qtr. hrs.)
A comprehensive treatment of the theory and behavior of basic constituents, such as optical fibers, light sources, photodetectors, connecting and coupling devices, and optical amplifiers. The basic design principles of digital and analog optical fiber transmission links. The operating principles of wave-length-division multiplexing (WDM) and the components needed for its realization. Description of the architectures and performance characteristics of complex optical networks for connecting users who have a wide range of transmission needs (SONET/SDH). Discussions of advanced optical communication techniques, such as soliton transmission, optical code-division multiplexing, (optical CDMA), and ultra-fast optical time-division multiplexing (OTDM). Laboratory.

ENEE 3641 Electromagnetic Compatibility (4 qtr. hrs.)
The study of the design of electronic systems so that they operate compatibly with other electronic systems and also comply with various governmental regulations on radiated and conducted emissions. Topics may include electromagnetic compatibility (EMC) requirements for electronic systems, non-ideal behavior of components, radiated emissions and susceptibility, conducted emissions and susceptibility, shielding, and system design for EMC.

ENEE 3646 CAD of Microwave Circuits (4 qtr. hrs.)
Microwave network analysis; analysis and design of planar transmission lines, impedance matching and tuning; analysis and design of 2-, 3- and 4-port passive networks; analysis and design of active microwave circuits; introduction to microwave systems. The lab portion incorporates software for analysis, design and optimization of passive and active, lumped and distributed circuits.

ENEE 3660 Communications Systems Design (4 qtr. hrs.)
Design and performance evaluation of terrestrial and space communications systems; error correction coding; spread spectrum communication; link budget analysis and environmental effects. System design considerations include engineering judgment decisions to implement optimum communication configurations such as data rates, bandwidth, modulation schemes and operating frequencies.

ENEE 3665 Introduction to Telecommunication Systems
(3 qtr. hrs.)
Introduction to queuing theory and its application to data communication network. Basic concepts in source coding and information protection, standardized digital data formatting, techniques for in-band signaling and current networking concepts.

ENEE 3670 Introduction to Digital Signal Processing
(3 qtr. hrs.)
Introduction to the theory and applications of digital signal processing (DSP). Special attention is paid to the fast Fourier transform and convolution and to the design and implementation of both FIR and IIR digital filters.

ENEE 3810 Special Topics (EE) (1-5 qtr. hrs.)
Special topics in electrical engineering as announced. May be taken more than once.

ENEE 4035 Nanophotonics (4 qtr. hrs.)
Nanophototonics provides high-speed, high-bandwith, and ultra-small optoelectronic components. This course will cover nanoscale processes, devices, and their applications for harnessing and manipulating light on the nanoscale.

ENEE 4310 Information Theory and Coding (3 qtr. hrs.)
Information and entropy; coding theory; error detection; correction codes; channel capacity; application to communications engineering.

ENEE 4325 Data and Computer Communications
(3 qtr. hrs.)
OSI model; protocols; physical layout; modulation; switching; network topology and routing algorithms; LANs, ISDN.

ENEE 4360 Digital and Space Communications
(3 qtr. hrs.)
Performance of digital systems; coherent signals; coding methods; optimum receivers; synchronization; spread spectrum systems; space communications.

ENEE 4416 Advanced Digital Signal Processing Topics
(4 qtr. hrs.)
Study of linear discrete-time systems used to perform operation on random processes for the purposes of signal detection, estimation, spectral estimation, enhancement and parametric modeling of signals and systems, linear difference equations, X-transforms, random sequences, state variables, matching filtering, Wiener filtering. Prerequisite: ENEE 3670.

ENEE 4425 Image Processing (3 qtr. hrs.)
Methods for coding, storing and filtering images via digital computer; image enhancement, restoration, sampling, understanding and pattern recognition.

ENEE 4450 Speech Processing (3 qtr. hrs.)
Vocal tract modeling, linear predictive modeling techniques, speech compression methods, introduction to speech recognition methods.

ENEE 4460 Real-Time Digital Signal Processing
(4 qtr. hrs.)
Digital signal processing algorithms and processing of discrete data, finite word length effects on filters, fixed point arithmetic and floating-point arithmetic. Overview of different architectures of digital signal processors. Programming of the DSP processor, implementation of DSP algorithms on DSP hardware in labs. Prerequisites: ENEE 3111 or ENEE 3670, ENCE 3210, or by permission of instructor.

ENEE 4610 Advanced Electromagnetics (4 qtr. hrs.)
Properties of electromagnetic radiation; guided waves; propagation; high-frequency techniques. Specific topics include: integral equations and the moment method; scattering; and Green's functions.

ENEE 4620 Advanced Optical Fiber Communication
(4 qtr. hrs.)
A comprehensive treatment of the theory and behavior of basic constituents, such as optical fibers, light sources, photodetectors, connecting and coupling devices, and optical amplifiers. The basic design principles of digital and

analog optical fiber transmission links. The operating principles of wave-length-division multiplexing (WDM) and the components needed for its realization. Descriptions of the architectures and performance characteristics of complex optical networks for connecting users who have a wide range of transmission needs (SONET/SDH). Discussions of advanced optical communication techniques, such as soliton transmission, optical code-division multiplexing, (optical CDMA) and ultra-fast optical time-division multiplexing (OTDM). Laboratory and project.

ENEE 4630 Optical Networking (4 qtr. hrs.)
This course provides a technical overview of optical networking. It gives students a solid understanding of optical networking field principles and practice. Underlying principles are reviewed along with common optical solutions and practices. It explains and provides practical tips on how to design and implement Networks. Examples are used to demonstrate key concepts of ATM, SONET/SDH and DWDM implementation.

ENEE 4671 Computer Aided Design of Microwave Circuits (4 qtr. hrs.)
Microwave network analysis; analysis and design of planar transmission lines, impedance matching and tuning; analysis and design of 2-, 3-, and 4-port passive and active networks; analysis and design of active microwave circuits; introduction to microwave systems. The lab portion incorporates software for analysis, design and optimization of passive and active, lumped and distributed circuits. Prerequisite: ENEE 2620.

ENEE 4720 Modern and Digital Control Systems (4 qtr. hrs.)
State space analysis and synthesis of continuous and discrete linear systems; Z-transform methods; controlability, observability, minimal realization and pole-assignment design.

ENEE 4750 Adaptive Control Systems (4 qtr. hrs.)
Adaptive control techniques; learning systems; and stochastic learning system theory are covered.

ENEE 4800 Advanced Topics (EE) (1-5 qtr. hrs.)
Various advanced topics in electrical engineering as announced. May be taken more than once.

ENEE 4991 Independent Study (1-10 qtr. hrs.)

ENEE 4995 Independent Research (1-18 qtr. hrs.)

ENGINEERING (GENERAL)

ENGR 3100 Instrumentation and Data Acquisition (4 qtr. hrs.)

ENGR 3610 Engineering Analysis (3 qtr. hrs.)
Applied mathematics for engineers. Generalized Fourier analysis, complex variables, vector calculus, introduction to Bessel functions, and applied probability and statistics.

ENGR 3630 Finite Element Methods (4 qtr. hrs.)
Introduction to the use of finite element methods in one or two dimensions with applications to solid and fluid mechanics, heat transfer and electromagnetic fields; projects in one or more of the above areas.

ENGR 3721 Controls (3 qtr. hrs.)
Modeling, analysis and design of linear feedback control systems using Laplace transform methods. Techniques and methods used in linear mathematical models of mechanical, electrical, thermal and fluid systems are covered. Feedback control system models, design methods and performance criteria in both time and frequency domains. A linear feedback control system design project is required.

ENGR 3730 Introduction to Robotics (4 qtr. hrs.)
Introduction to the analysis, design, modeling, and application of robotic manipulators. Review of the mathematical preliminaries required to support robot theory. Topics include forward kinematics, inverse kinematics, motion kinematics, trajectory control and planning, and kinetics. Applications include programming and task planning of a manufacturing robot manipulator

ENGR 3750 Energy Conversion and Power Systems (3 qtr. hrs.)
Introduction to the generation, distribution and practical aspects of electrical power and electromagnetic energy conversions and machinery to include shafts and torque couplings. Topics include power plants, electrical grid standards and components, single-phase and three-phase power machinery and circuits, transformers, generators, motors and safety in the power generation plant and the distribution system..

ENGR 3800 Special Topics (ENGR) (1-5 qtr. hrs.)
Various topics in engineering as announced. May be taken more than once.

ENGR 3900 Engineering Internship (1-4 qtr. hrs.)
Students in engineering may receive elective credit for engineering work performed for engineering employers with the approval of the chair or associate chair of the department. At the end of the term, a student report on the work is required, and a recommendation will be required from the employer before a grade is assigned. Junior, senior or graduate status in engineering is normally required. May not be used to satisfy technical requirements. (May be taken for a maximum of 6 qtr. hrs.)

ENGR 4100 Instrumentation and Data Acquisition (4 qtr. hrs.)
This course will examine different instrumentation techniques and describe how different measurement instruments work. Measurement devises will include: Length, Speed, Acceleration, Force, Torque, Pressure, Sound, Flow, Temperature, and Miscellaneous. The course will examine the acquisition, transmission and manipulation of data.

ENGR 4200 Introduction to Nanotechnology (4 qtr. hrs.)
In this highly interdisciplinary series of lectures spanning across Engineering, Physics, Chemistry and Biology an introduction to the subject of nanotechnology is provided. The most important recent accomplishments so far in the application of nanotechnology in several disciplines are discussed. Then a brief overview of the most important

instrumentation systems used by nanotechnologists is provided. The nature of nanoparticles, nano particle composites, carbon nanostructures, including carbon nanotubes and their composites is subsequently discussed. The course also deals with nanopolymers, nanobiological systems, and nanoelectronic materials and devices. The issue of modeling of nanomaterials and nanostructures is also covered in this class. Multiscale modeling based on finite element simulations, Monte Carlo methods, molecular dynamics and quantum mechanics calculations are briefly addressed. Most importantly, students should obtain appreciation of developments in nanotechnology outside their present areas of expertise.

ENGR 4210 Introduction to Nano-Electro-Mechanical Systems (4 qtr. hrs.)
This course familiarizes science and engineering students to the electromechanical aspects of the emerging field of Nanotechnology (NEMS). NEMS is a relatively new and hightly multidisciplinary field of science and technology with applications in the state-of-the-art and future sensors, actuators, and electronics. This course starts with an overview of nanotechnology and discussion on the shifts in the electromechanical behavior and transduction mechanisms when scaling the physical dimensions from centimeters to micro-meters and then down to nanometers. Several electromechanical transduction mechanisms at the micro and nanoscale will be presented and discussed in an application-based context. New electromechanical interactions appearing in the nano and molecular scale, such as intra-molecular forces and molecular motors, will be discussed. A detailed discussion and overview of nanofabrication technologies and approaches will also be provided in this course.

ENGR 4215 NEMS and Nanofabrication Lab (4 qtr. hrs.)
This course provides science and engineering students with comprehensive hands-on experience in design, fabrication and characterization of Nanoscale Electromechanical Systems (NEMS). This laboratory-based course starts with a number of sessions including brief lectures reviewing the fundamentals and theories followed by pre-designed lab experiments. The students are then provided with a choice of different comprehensive design and implementation projects to be performed during the quarter. The projects include design, layout, fabrication, and characterization of the devices potentially resulting in novel findings and publications.

ENGR 4220 MEMS and Microsystems (4 qtr. hrs.)
This course will introduce students to the multi-disciplinary field of Micro-Electro-Mechanical-Systems (MEMS) technology. MEMS and Microsystem technology is the integration of micro-scale electro-mechanical elements, sensors, actuators, and electronics on a common substrate or platform through semiconductor microfabrication technologies. The course will give a brief overview of the involved physical phenomena, electromechanical transduction mechanisms, design principles, as well as fabrication and manufacturing technologies.

ENGR 4350 Reliability (4 qtr. hrs.)
An overview of reliabilty-based design. Topics include: fundamentals of statistics, probability distributions, determining distribution parameters, design for six sigma, Monte Carlo simulation, first and second order reliabilty methods (FORM, SORM), Most Probable Point (MPP) reliabilty methods, sensitivity factors, probabilistic design.

ENGR 4620 Optimization (3 or 4 qtr. hrs.)
Engineering problems will be formulated as different programming problems to show the wide applicability and generality of optimization methods. The development, application and computational aspects of various optimization techniques will be discussed with engineering examples. The application of nonlinear programming techniques will be emphasized. A design project will be assigned.

ENGR 4745 Advanced Nonlinear Control Systems (3 qtr. hrs.)
Limit cycles; functional analysis approach to input-output stability; analysis/synthesis of time-varying systems; feedback linearization, bangbang control.

ENGR 4810 Advanced Topics (1-5 qtr. hrs.)
Various advanced topics in engineering as announced. May betaken more than once.

ENGR 4900 Seminar (1 qtr. hr.)
Current topics in engineering. May betaken more than once.

ENGR 4930 Advanced Project (4 qtr. hrs.)
Required of students in the joint business and engineering MS program.

ENGR 4991 Independent Study (1-5 qtr. hrs.)

ENGR 4992 Directed Study (1-10 qtr. hrs.)

ENGR 4995 Independent Research (1-18 qtr. hrs.)

ENGR 5995 Independent Research (1-18 qtr. hrs.)
Doctoral research.

MECHANICAL ENGINEERING

ENME 3230 Introduction to Nondestructive Evaluation (3 qtr. hrs.)
Principles of nondestructive evaluation, including ultrasonic, radiographic, magnetic, electrical, penetrant, acoustic emission, etc. Covers expected results for flaw and materials characterization. Current literature approaches are examined.

ENME 3511 Machine Design (3 qtr. hrs.)
Application of statics, dynamics, mechanics of materials and manufacturing processes to the design of machine elements and systems; properties of materials and design criteria; synthesis and analysis of a machine design project.

ENME 3540 Introduction to Continuum Mechanics (3 qtr. hrs.)
Kinematics of deformation, measures of stress, equations of motion for deformable solids; constitutive relations for elastic, viscoelastic and elastic-plastic materials; work and energy.

GRADUATE-LEVEL ENGINEERING COURSE DESCRIPTIONS

ENME 3545 Mechanisms (4 qtr. hrs.)
Synthesis, analysis and use of mechanisms. The mechanisms to be studied include: cams, gears and planar linkages, with an emphasis on planar linkages.

ENME 3550 Mechanical Vibrations (3 qtr. hrs.)
Basic mechanical vibrations including: dynamics; periodic motion; energy methods and Rayleigh's principle; forced periodic motion; initial conditions and transient vibration; damping; damped forced vibrations, several degrees of freedom; torsional vibration; discrete and distributed systems.

ENME 3555 Advanced Dynamics (3 qtr. hrs.)
Introduction to variational principles of mechanics, Lagrangian mechanics, three-dimensional rigid body mechanics, other topics. Applications.

ENME 3560 Advanced Mechanisms and Machinery (3 qtr. hrs.)
Advanced topics in design and analysis of mechanisms. Topics may include: force analysis of mechanisms, force and moment balancing, flywheels, flexible mechanisms.

ENME 3651 Computational Fluid Dynamics (4 qtr. hrs.)
This course introduces principles and applications of computational methods in fluid flow and topics chosen from heat transfer, mass transfer or two-phase flow. The conservation equations, their discretations and solutions are presented. Convergence and validity of solutions along with computational efficiency are explored. Students learn to apply these techniques using the latest software packages.

ENME 3730 Advanced Engineering Thermodynamics (3 qtr. hrs.)
Advanced topics in thermodynamics. Introduction to statistical thermodynamics.

ENME 3820 Special Topics (ME) (1-5 qtr. hrs.)
Various mechanical engineering topics as announced. May be taken more than once.

ENME 3820 Reliability (4 qtr. hrs.)

ENME 3860 Introduction to Air Pollution (3 qtr. hrs.)
The thermodynamics, kinetics and photochemistry of air pollution. Origins and effects of particulate pollution, including light scattering. Effects of meteorology on air pollution.

ENME 4020 Advanced Finite Element Analysis (4 qtr. hrs.)
The advanced use of finite element methods in two and three dimensions with applications to solids. Prerequisite(s): ENGR 3630 or Instructor Permission.

ENME 4310 Computational Methods for Mechanics and Materials (4 qtr. hrs.)
An introductory course for the general-purpose computational methods in advanced multiscale materials and mechanics. Students will learn the fundamentials on the numerical methods used in mechanical and materials engineering.

ENME 4360 Advanced Elasticity (3 qtr. hrs.)
Stress tensor; analysis of strain; conservation laws; linear elastic stress strain relationships; solution of problems in elasticity by potentials; 2-D problems in elasticity; energy theorems; wave propagation; numerical techniques.

ENME 4370 Plasticity (4 qtr. hrs.)
Flow theory of plasticity; yield surface; plastic potential; loading-unloading condition; hardening rules; deformation theory of plasticity; elastic-plastic problems; slip line theory; statistically indeterminate problem; numerical methods in plasticity.

ENME 4400 Fatigue (4 qtr. hrs.)
A detailed overview of fatigue. Topics include: stress life and strain life approaches, fracture mechanics, constant amplitude and spectrum loading, life prediction, fatigue at notches, microstructural effects, environmentally assisted fatigue, retardation and acceleration, multi-axial fatigue, design against fatigue and reliability.

ENME 4650 Advanced Fluid Dynamics (4 qtr. hrs.)
Physical properties of liquids and gases; turbulence and closure models; surface waves and instabilities; non-Newtonian fluid behavior; conformal mapping and airfoil theory.

ENME 4660 Micro Heat Exchangers (4 qtr. hrs.)
This course explores the advance principles and applications of fluid dynamics and heat transfer through the application to micro fluidic heat exchanger design and optimization. Students will utilize MathCAD extensively to seek optimized exchanger performance within a clearly defined design space. Students will also build small scale heat exchangers from their optimized designs. Prerequisite: ENME 2671

ENME 4670 Advanced Computational Fluid Dynamics (4 qtr. hrs.)
This course will build on the principles and applications of computational methods in fluid flow and topics chosen from heat transfer, mass transfer, and two-phase flow. Specifically, Monte Carlo and volume of fluid techniques will be discussed at length. Additionally, students will learn how to set up automated design optimization using the latest software packages. If time allows, students will also get an introduction to fluid-solid interaction modeling. Prerequisite: ENME 3651.

ENME 4800 Advanced Topics (ME) (1-5 qtr. hrs.)
Determined by interest and demand. May be taken more than once for credit.

ENME 4991 Independent Study (1-10 qtr. hrs.)

ENME 4995 Independent Research (1-18 qtr. hrs.)

MECHATRONIC SYSTEMS ENGINEERING

ENMT 3210 Mechatronics I (4 qtr. hrs.)
This course provides basic concepts from electrical, mechanical and computer engineering as applied to mechatronic systems; and is intended to serve as a foundation course for father exploration in the area of mechtaronics. Prerequisite: senior or graduate standing.

GRADUATE-LEVEL ENGINEERING COURSE DESCRIPTIONS

ENMT 3800 Special Topics (Mechatronics) (1-5 qtr. hrs.)
Various topics in mechatronic systems engineering as announced. May be taken more than once.

ENMT 4000 Space Systems Design I (4 qtr. hrs.)
The application of advanced theory and concepts as they relate to the development of a spacecraft and missile subsystems, and how these subsystems are related under the umbrella of systems engineering. The course emphasizes practical aspects of space systems design and integration, and is team-taught by faculty and functional experts in the various fields. Lecture topics include aerospace materials, mechanics, thermal control, embedded systems, distributed sensor networks and aerospace probability and statistics.

ENMT 4010 Space Systems Design II (4 qtr. hrs.)
The continuation of Space Systems Design I. Lecture topics include payload communications, guidance and control, spacecraft electric power, propulsion systems, radiation and avionics and sensor subsystems.

ENMT 4100 Systems Engineering (4 qtr. hrs.)
Provides a framework for understanding and acquiring the knowledge, tools and skills needed by explicitly "systems-trained engineers, to effectively interact with specialist engineers and project managers in the engineering of complex, large-scale systems. Emphasis is on the development of a life-cycle model for systems engineering processes, to reduce the risk inherent in each life-cycle stage.

ENMT 4220 Mechatronics II (4 qtr. hrs.)
This course combines systems design and integration with a real-world project involving the design and fabrication of an integrated system. Prerequisite: Mechatronics I or equivalent.

ENMT 4730 Advanced Ground Robotics (4 qtr. hrs.)
Introduction to path planning and sensing and estimation for robotic manipulators and mobile robots. Review of the mathematical preliminaries required to support robot theory. Topics include advanced sensors, mobile robot mechanisms, advanced manipulator mechanisms, path planning in 2-D and 3-D, and simultaneous localization and mapping. Applications include task and motion planning for idealized and real robots. Prerequisites: ENGR 3730 or permission of instructor.

ENMT 4734 Unmanned Aerial Systems
(4 qtr. hrs.)
Unmanned Aerial Vehicles (UAVs), or Unmanned Aircraft Systems (UAS) as is the preferred term by the US DOD, have seen unprecedented levels of growth in military and civilian application domains. Fixed-wing aircraft, heavier or lighter than air, rotary-wing (rotocraft, helicopters), vertical take-off and landing (VTOL) unmanned vehicles are being increasingly used in military and civilian domains for surveillance, reconnaissance, mapping, cartography, border patrol, inspection, homeland security, search and rescue, fire detection, agricultural imaging, traffic monitoring, to name just a few application domains. This course offers a very comprehensive study of UAS that includes: history of modeling, control and navigation fundamentals for both teleoperation, semi-autonomous and fully autonomous flights; see-and-avoid systems for different classes of UAS; integration of UAS into the National Airspace System (NAS); applications and case studies. Prerequisites are Robotics, Controls, and/or Permission by the instructor.

ENMT 4800 Advanced Topics (Mechatronics)
(1-5 qtr. hrs.)
Various topics in mechatronic systems engineering as announced. May be taken more than once.

ENMT 4991 Independent Study (1-10 qtr. hrs.)

ENMT 4995 Independent Research (1-18 qtr. hrs.)

MATERIALS SCIENCE

MTSC 3110 Thermodynamics of Solids (3 qtr. hrs.)
Relations among thermodynamic quantities, thermodynamics of phase transformations, chemical reactions, solutions, alloys and phase diagrams. Applications to solid-state properties of materials.

MTSC 3800 Special Topics (Materials Science) (1-5 qtr. hrs.)
Various topics in Materials Science as announced as announced. May be taken more than once.

MTSC 4010 Mechanical Behavior of Materials (4 qtr. hrs.)
Effects of microstructure on mechanical behavior of materials; emphasis on recent developments in materials science, fracture, fatigue, creep, wear, corrosion, stress rupture, deformation and residual stress.

MTSC 4020 Composite Materials I (4 qtr. hrs.)
An introduction to composite materials: properties of fibers and matrices, fiber architecture, elastic deformation of laminae and laminates, interfaces in composites.

MTSC 4130 Introduction to Surface Science (3 qtr. hrs.)
Overview of the fundamentals of surface science and processes with an emphasis on the solid/gas interface. Topical areas include topography, shape, depth, composition, purity, structure and methods used to elucidate. The experimental aspects will be emphasized blending backgrounds in chemistry, physics, materials and mathematics. Theoretical and experimental aspects of interfacial interactions will be considered with particular attention focused on chemical absorption and desorption. Surface processes include surface diffusion and chemisorption as a precursor to oxidation and catalysis.

MTSC 4150 Diffraction and Structure I (3 qtr. hrs.)
Properties of X-rays, geometry of crystals, calculation of directions and intensities of diffracted beams from polycrystalline samples, experimental methods including computerized data acquisition and data reduction, detector characteristics, search/match methods for phase identification, determination of crystal structure (indexing)/ Laboratory exercises to illustrate the above.

MTSC 4215 Composite Materials II (3 qtr. hrs.)
A continuation of MTSC 4210: strength and toughness of composites, thermal behavior, fabrication methods, examples of applications.

GRADUATE-LEVEL ENGINEERING COURSE DESCRIPTIONS

MTSC 4230 Polymer Science I (3 qtr. hrs.)
Survey of common synthetic organic polymers; their bonding, classification, chemical structure and polymerization methods; chemical arrangements of repeat units; tacticity, copolymers, molecular weight averages and distributions; structure of amorphous polymers; chain conformation in single crystals and spherulites; transitions in polymers; glass/rubber, melting, crystallization; structure characterization techniques.

MTSC 4250 Structure & Properties of Ceramics I
(3 qtr. hrs.)
Review of structural classes of ceramics, structural imperfections, diffusion; phase diagrams in ceramic systems; selected phase transformations, reactions with and between ceramics, sintering and grain growth.

MTSC 4310 Design with Materials with Variable Properties (3 qtr. hrs.)
Development of the interrelationships of the following factors in design with real materials: variability in mechanical material properties, statistical design conditions, nondestructive evaluation, proof testing, product liability/lawsuits, desirable reliability/economics.

MTSC 4450 Fracture Mechanics (4 qtr. hrs.)
Topics include stress field at a crack tip, linear elastic fracture mechanics, energy release rate, stress intensity factors, plastic zones, plane stress, plane strain, fracture toughness, Airy stress functions, elastic-plastic fracture mechanics, J integral, crack tip opening displacements, experimental testing, fatigue, life prediction, crack closure, weight functions, failure analysis.

MTSC 4800 Advanced Topics (MTSC) (1-5 qtr. hrs.)
Selected topics (depending on student and faculty interest): fracture mechanics, fatigue, nonlinear constitutive models, dynamic behavior of materials, corrosion resistant design, thermodynamics of solids II.

MTSC 4900 Materials Science Seminar (1 qtr. hr.)
Weekly presentations by graduate students, faculty, outside speakers, etc., on research in progress or other topics of interest.

MTSC 4991 Independent Study (1-10 qtr. hrs.)

MTSC 4995 Independent Research (1-18 qtr. hrs.)
MS research.

MTSC 5995 Independent Research (1-18 qtr. hrs.)
Doctoral research.

BIOLOGY

BIOL 3642 Neuropharmacology (4 qtr. hrs.)
How psychoactive drugs exert their effects on the nervous system; drugs of abuse and drugs used in the treatment of psychotic and neurodegenerative disorders. Prerequisite: BIOL 3640.

BIOL 4090 - Biometry (4 qtr. hrs.)
Statistic on biological research; emphasis on procedures, applications of regression, correlation, analysis of variance, and nonparametric tests. Include instruction on computeraided (Mac and PC) statistical analysis and presentation of results.

BUSINESS

BUS 4610 - The Essence of Enterprise (4 qtr. hrs.)
Today's business environment is increasing characterized by complex questions without clear black and white answers that span well beyond the historically narrow focus on the enterprise. Managers of tomorrow must be equipped with analytical and conceptual skills that allow them to see connections between social and environmental challenges and opportunities from local to global levels and how they interact and influence enterprise level value creation and innovation in a responsible manner. This course provides a perspective - i.e. worldview - that appropriately places the enterprise in the context of an interconnected world where success, organizationally and personally, is determined by how well one applies the necessary functional skills and organizational understanding to opportunities and challenges framed by globalization, both shared and disparate values, and the need for creativity, innovation, and entrepreneurial spirit. This course draws on the history of business practice and leadership to provide a foundation for personal self-discovery and professional direction.

BUS 4615 - Leading at the Edge (2 qtr. hrs.)
Connects values, globalization, and innovation through a mix of classroom and outdoor experiential learning formats. The course is a two credit hour complement to The Essence of Enterprise course. Using the metaphor of the 10th Mountain Division, the course builds a foundation for learning at Daniels through introductory looks at leadership, team building, and creative problem solving. Through metaphor and experience, the course will bond the cohorts to each other and enhance self confidence to succeed under difficult and changing conditions. The 10th Mountain Division was created out of a global crisis and trained at Camp Hale Colorado, located between Leadville and Vail, during the 1940s. This experience resulted in fourteen patents, including predecessors to the snow cat, snowmobile, and various other forms of outdoor equipment. Following WWII, members of the 10th were responsible for building the country's most famous ski resorts, such as Aspen and Vail, along with the 10th Mountain Hut System. Individual members became successful businessmen, social entrepreneurs, and civil servants forming companies such as NIKE, leading organizations like the Sierra Club, and founding the Colorado Outdoor Education Center (where training for this course takes place). The group is renowned for exemplary leadership, passion, team dynamics, innovation, and ethics within a global environment.

BUS 4620 - Ethics for the 21st Century Professional (4 qtr. hrs.)
A fundamental purpose is to engage students in ongoing reflection and dialogue about their responsibilities as managers and leaders. Of particular emphasis are the ethical, professional and social responsibilities of managers and leaders, especially as it relates to numerous stakeholders and communities. This course focuses on the idea of "community" and the social relationships of managers and business organizations in their communities. Roles and responsibilities of managers and business firms

will be examined by analyzing a variety of issues that managers will face during their careers. These specific issues will be examined in terms of their legal, public policy, and ethical dimensions. The goal is to provide students with generalized understanding and skills that can be employed in dealing with other issues that may emerge in their business careers.

BUS 4630 - Creating Sustainable Enterprises (4 qtr. hrs.)
A sustainable enterprise is defined as any human endeavor with integrity in three interconnected dimensions - environmental, cultural, and economic - and whose collective actions meet the needs of the enterprise and its stakeholders today without compromising the ability of future generations to meet their needs. The fundamental purpose of this course is to help prepare students for careers in which success requires a worldview that extends beyond the enterprise level in order for managers to create sustainable cultural, social, and financial value for the organization and society in a responsible manner.

BUS 4635 - Global Enterprise Challenges (2 qtr. hrs.)
As students complete the integration of material from the Compass sequence, this class will provide an opportunity for the students to extensively apply the material through: case analysis, presentation, critique of other presentations, and integration of MBA Compass material and first year MBA Core material as appropriate.

BUS 4640 - Innovation Design & Execution (4 qtr. hrs.)
In the last century, the technologies of the industrial age - telegraph, railroads, electricity, radio, telephone, television, automobiles, airplanes, computers - have dramatically altered not only the way business is conducted, but the way we live and learn. These technologies have also enabled undesirable and unintended consequences - urban sprawl, global warming, terrorism, weapons of mass destruction, stress, obesity. Where is technology taking us? In this course, we will look at innovation, creativity, entrepreneurship and design, and the role each can play in creating a better business world, a business world less driven by science fiction than inspired by social fiction, a business world which begins to shift from an industrial age of ever more encompassing technology to a creative economic environment based less on stuff and more on people and their needs.

CHEMISTRY

CHEM 3110 Chemical Systems I (3 qtr. hrs.)
(3110) Advanced discussion of modern concepts of organic chemistry; bonding, stereochemistry, reaction mechanisms. Prerequisite: CHEM 2453 and equivalent of one year of physical chemistry.

CHEM 3120 Chemical Systems II (3 qtr. hrs.)
Interpretation of trends in the chemistry of the elements in terms of orbital interactions. Most examples will be taken from the third transition metals and the boron and carbon groups. Prerequisites: CHEM 2131, 3310 and CHEM 3110.

CHEM 3130 Chemical Systems III (3 qtr. hrs.)
Advanced-level physical biochemistry course intended for advanced-level undergraduates and graduate students. Focuses on kinetic, thermodynamic and dynamic aspects of biopolymers; delineates the relationship of these properties to the mechanism and function of biological macromolecules. Prerequisites: CHEM 3811, 3812, 3813, CHEM 3610 or the equivalent.

CHEM 3220 Advanced Analytical Chemistry (3 qtr. hrs.)
This is a course in computational methods in chemistry. Principles of chemical instrumentation applied to analytical measurements; principles, instrumentation and applications of spectrometric and chromatographic measurements. Prerequisites: CHEM 2011 and 3621.

CHEM 3310 Molecular Structure and Energetics I (3 qtr. hrs.)
Topics to be covered are fundamentals of quantum chemistry, introduction to symmetry and molecular structure of small and large systems.

CHEM 3320 Molecular Structure and Energetics II (3 qtr. hrs.)
Principles of chemical instrumentation applied to analytical measurements; principles, instrumentation and applications of spectrometric and chromatographic measurements. Prerequisites: CHEM 2011 and 3621...

CHEM 3620 Physical Chemistry II (3 qtr. hrs.)
Fundamentals of quantum chemistry, including theories of atomic and molecular structure and spectroscopy. Includes laboratory. May be taken for graduate credit by students in disciplines other than chemistry.

CHEM 3621 Physical Chemistry III (3 qtr. hrs.)
Fundamentals of kinetic theory and statistical mechanics. May be taken for graduate credit by students in disciplines other than chemistry.

COMPUTER SCIENCE

Comp 3351 Programming Languages (4 qtr. hrs.)
Programming language as a component of software development environment; binding, scope, lifetime, value and type of a variable; run-time structure - static, stack-based and dynamic languages; parameter passing - call by reference, value, result, value-result and name; subprogram parameters; role played by side effects, dangling pointers, aliases and garbage; garbage collection; data abstraction - study of object-oriented, functional, and logic languages. Prerequisites: COMP 2370 and COMP 2691.

COMP 3381 Software Engineering (4 qtr. hrs.)
Design and implementation, testing and maintenance of large programs in a dynamic environment, and systematic approach to software design with emphasis on portability and ease of modification. Prerequisite: COMP 2370.

COMP 3421 Database Organization and Management (4 qtr. hrs.)
An introductory class in databases explaining what a database is and how to use one. Topics include database design, ER modeling, database normalization, relational algebra, SQL, physical organization of records an clocks, heap files, sorted files, hashing, extendible hashing, linear hashing and B trees. Each student will design, load, query and update a nontrivial database using the Oracle DMBS. Prerequisite: COMP 2370.

COMP 3704 Computer Security (4 qtr. hrs.)

COMP 4704 Bioinformatics (4 qtr. hrs.)

PHYSICS

PHYS 3111, 3112 Quantum Physics I, II (4 qtr. hrs. each)
Introduction to quantum mechanics. Atomic, molecular, nuclear and particle physics.

PHYS 3411, 3412 Solid State Physics I, II (3 qtr. hrs. each)
Crystallographic properties, X-ray diffraction; elastic properties, thermal properties; classification of basic solid types. Electrical and magnetic properties of solids; semiconductor materials and devices; superconductivity.

PHYS 3841, 3842 Thermal Physics I, (4 qtr. hrs. and 2 qtr. hrs, respectively)
Laws of thermodynamics; thermal properties of gases and condensed matter; kinetic theory of gases, classical and quantum statistics. Usually offered only alternate years.

PHYS 4111, 4112, 4113 Quantum Mechanics I, II, III (3 qtr. hrs. each)
The mathematical formalism of quantum mechanics and its interpretation; stationary states; perturbation theory; scattering theory; angular momentum; identical particles.

PHYS 4411, 4412, 4413 Advanced Solid State Physics I, II, III (3 qtr. hrs. each)
Structure of solids; thermodynamics, mechanical, optical and electrical properties; alloys; band theory of solids; growth superconductivity.

PHYS 4551, 4552, 4553 Mathematical Physics I, II, III (3 qtr. hrs. each)
Methods of analysis; expansion theory; solution of differential equations; special functions and their use in solution of problems of physics; study of symmetry; theory of groups and group presentations.

PHYS 4611, 4612 Advanced Electricity and Magnetism I, II (3 qtr. hrs. each)
Classical and quantum mechanical theory of assemblies of non-interacting particles; Boltzmann, Bose-Einstein, Fermi-Dirac and Gibbs statistics, with application to ordinary dilute gases; electrons in metals; liquid helium; extensions from kinetic theory and thermodynamics.

PHYS 4811, 4812, 4813 Statistical Mechanics I, II, III (3 qtr. hrs. each)
Classical and quantum mechanical theory of assemblies of non-interacting particles; Boltzmann, Bose-Einstein, Fermi-Dirac and Gibbs statistics, with application to ordinary dilute gases; electrons in metals; liquid helium; extensions from kinetic theory and thermodynamics.