Introduction to All Graduate Programs

The Department of Engineering at the University of Denver offers a number of graduate programs in several areas of engineering.

Traditional Engineering Programs

- MS in computer engineering, electrical engineering, and mechanical engineering
- PhD in engineering, with specialization in computer, electrical, or mechanical engineering

Joint Programs

The department participates with the departments of chemistry and biochemistry, and physics and astronomy in an interdisciplinary PhD in materials science. Two additional programs combine the strengths of the engineering department with the department of computer science, leading to a joint MS in computer science and engineering, and with the Daniels College of Business, leading to a joint MS in management and engineering. In these joint programs, the engineering component may be chosen from computer, electrical, or mechanical engineering.

Part-Time Study

Our department recognizes that a student may be employed full time while studying for a degree. Therefore, most courses are offered at times and on days that will permit a student to complete the program by taking courses either late in the day or outside of normal business hours. Many employers will permit additional flexibility by releasing employees early to attend classes. The MS degree programs can generally be completed in about four years if one course is taken each quarter, but it is usually possible to take two courses per quarter, bringing completion time closer to the more common duration of two years. In case of unforeseen hardships or exigency, the time limitation on credit may be extended from five to eight years by the department through a written petition. For part-time students who are working in industry positions and who have chosen the thesis option, a topic related to the job function may be acceptable as the thesis research topic. Furthermore, a qualified staff member at the place of employment may serve as an adjunct faculty on the thesis committee.

Students not interested in pursuing a degree but interested in taking an occasional course may register as special status students by following an abbreviated admissions process. However, only 15 quarter hours earned as a special status student may be applied toward an MS or PhD degree.

Application Process

A completed application to any of the programs (except the management and engineering program, for which cf. the appropriate section below) consists of the following:

- University of Denver application for admission to graduate study (available from the department) or online at the engineering web site, www.engr.du.edu
- supplemental data form (available from the graduate admissions office)
- two official transcripts from each college and/or university attended
- $50 application fee
- general Graduate Record Examination (GRE) scores (subject test not required)
- three letters of recommendation from individuals who can comment on the candidate’s likelihood of success in the program
- TOEFL and TSE scores where applicable, as described below
- a personal statement describing why the applicant is seeking the degree

The university’s application and instructions for domestic students (US citizens) are available on the web at: http://www.du.edu/grad/application.html
The university’s application and instructions for international students are available on the web at: http://www.du.edu/grad/international.html
Application forms can also be obtained by mail from the addresses at the end of this booklet.

Applications are accepted on a rolling basis, and students are admitted for the fall, winter or spring quarters. However, graduate teaching assistantships are awarded in April of each year to begin the following fall
quarter. Students interested in competing for GTAs are therefore advised to submit their applications by February to ensure consideration for an appointment in September of a given year. Students whose native language is not English must demonstrate fluency in English. A score of at least 570 in the Test of English as a Foreign Language (TOEFL) is required (or a score of at least 230 in the computer version of the TOEFL). If such students wish to apply for a graduate teaching assistant (GTA) position, they are required to have scored at least 50 on the Test of Spoken English (TSE).

**Master of Science in COMPUTER, ELECTRICAL, or MECHANICAL ENGINEERING**

The Master of Science (MS) in Computer Engineering, Electrical Engineering, or Mechanical Engineering is designed to advance the student’s knowledge in several areas of engineering. Each degree provides breadth through its flexible minor or technical elective requirement, while permitting the student to achieve depth in one of several areas of specialization; specifically these areas are as follows for the MS (CPE): communications, DSP and networking; robotics, embedded systems, and instrumentation; computer systems engineering; software engineering. For the MS (EE): electromagnetics and optical communications semiconductors; signal processing and communications; and systems and controls. For the MS (ME): fluid mechanics and heat transfer, mechanical design and analysis, and structure and behavior of materials. These areas of specialization have been selected to coincide with those of high current interest as well as those emerging technologies that hold promise of increasing importance for the future. The purpose of these programs is to serve the profession of engineering and the Colorado community through advanced study in computer, electrical or mechanical engineering and related fields. Each program will also prepare the students for academic and industrial advancement. All programs offer a Thesis and a Non-Thesis option.

**ADMISSION TO THE PROGRAMS**

A bachelor of science degree in computer engineering (BSCPE), electrical engineering (BSEE) or closely related field, is required for admission to the MS (CPE) or MS (EE) programs, respectively. A bachelor of science degree in mechanical engineering (BSME) or closely related field is required for admission to the MS(ME) program. Those students whose backgrounds differ significantly from EAC/ABET accredited BS computer/electrical/mechanical engineering programs may be required to complete prerequisite undergraduate courses; such courses are not considered part of the 45 credit-hour requirement for the degree. A competency examination may be required of MS (CPE) and MS (EE) candidates who do not possess a 3.0 GPA or a BS in electrical, electronic, or computer engineering from an EAC/ABET accredited program. A competency examination may be required of MS (ME) candidates who do not possess a 3.0 GPA or a BS in mechanical, civil, aerospace, or materials science or materials engineering from an EAC/ABET accredited program. Students with BS degrees in physics, mathematics, computer science, engineering science, electrical or mechanical engineering technology, engineering physics or similar bachelor of science degrees may also be admitted. However, these students should be able to demonstrate competency in the following basic subjects by passing an appropriate competency examination:

**MS (CPE)**
- Circuits and Electronics
- Digital Systems
- Computer Organization
- A high or low level computer language

**MS (EE)**
- Digital Design Methods
- Physical Electronics
- Introductory Electromagnetics
- Signals and Systems
- Principles of Communications
- Circuits and Electronics

**MS (ME)**
- Mechanics
- Thermodynamics
- Fluid Mechanics
- Materials Science
Students may be admitted provisionally while they take the appropriate prerequisite courses should it be
determined from the competency examination or from the prior academic records that certain needed skills
are lacking. Through the satisfactory completion of the stated provisional requirements, the student’s status
will be changed from provisional to regular status.

PROGRAM REQUIREMENTS FOR THE MS (CPE), MS (EE), AND MS (ME) DEGREES

Minimum Credit Requirements

Every candidate for the MS (CPE), MS (EE) or MS (ME) degree must complete 45 quarter hours of credit, at
least 36 of which must be completed at the University of Denver.

Program Structure

Candidates for the degree of Master of Science in Computer Engineering, Electrical Engineering or
Mechanical Engineering may elect either the Thesis or Non-Thesis Option. This choice may be made at any
time, although a delay in declaration may impact the completion date. Students who are GTAs or who
receive financial support from a University research grant as graduate research assistants (GRAs) are
required to elect the thesis option. These programs are designed to be completed in about seven quarters if
two courses (6 or 7 qtr. hrs.) are taken each quarter.

Non-Thesis Option: The more flexible of the two options, this is designed with the working professional in
mind. For this option, a grade of B or better must be obtained in each course in order for that course to count
toward the 45 QH requirement. The basic structure of the minimum 45 quarter hours for the non-thesis
option is as follows:

- Specialty Track (with a minimum of four 4000 level courses, of at least 3 QH each) 18 QH
- Technical Electives (with a minimum of two 4000 level courses, of at least 3QH each) 18 QH
- Advanced Mathematics Requirement 6 QH
- Engineering Seminar 3 QH

45 QH

Thesis Option: A thesis permits a candidate to obtain depth in an area of study and is especially useful for
individuals seeking to pursue a subsequent degree. Thesis candidates work closely with a thesis advisor.
The thesis option is required for all Graduate Research Assistants (GRAs) and Graduate Teaching
Assistants (GTAs). The basic structure of the minimum 45 quarter hours for the thesis option is as follows:

- Specialty Track (with a minimum of three 4000 level courses, of at least 3QH each) 15 QH
- Flexible Minor (with a minimum of one 4000 level course, of at least 3QH each) 9 QH
- Advanced Mathematics Requirement 3 QH
- Thesis 15 QH
- Engineering Seminar 3 QH

45 QH

Advanced Mathematics Requirement

All MS candidates must complete an Advanced Mathematics requirement. Advanced mathematics
courses at the 3000 or higher level are selected with the prior approval of the student’s advisor.

Engineering Seminar Requirement

All MS candidates must complete three quarter hours of Engineering Seminar (ENGR 4900). GRAs and
GTAs are required to attend the Engineering Seminar even when they are not formally enrolled in the
class.

Technical Electives Requirement (Non-Thesis Option)

A minimum of two of the technical elective courses must be at the 4000 level, (each with not less than 3 QH
credit) with one course selected from each of two of the other specializations offered for the degree chosen.
A course that appears in more than one specialization may only be counted towards one specialization. The
remaining technical electives are chosen from appropriate courses numbered 3000 or higher, offered by the
NSME (Natural Sciences, Mathematics, and Engineering) departments, with the prior approval of the student’s advisor.

**Flexible Minor Requirement (Thesis Option)**

At least one of the courses for the flexible minor must be at the 4000 level (with not less than 3 QH of credit) selected from one of the other specializations offered for the degree chosen. A course that appears in more than one specialization may only be counted towards one specialization. For the MS (CPE) and MS (EE) degrees, the remaining courses for the flexible minor must be selected from the other specializations offered for the degree chosen, with the prior approval of the student’s advisor. For the MS (ME) degree, the remaining courses for the flexible minor are chosen from appropriate courses numbered 3000 or higher, offered by the NSME (Natural Sciences Mathematics and Engineering) departments, with the approval of the student’s advisor.

**Specialization Requirements**

**Computer Engineering**

The MS (CPE) program offers four areas of specialization:

- Communications, DSP and Networking
- Robotics, Embedded Systems and Instrumentation
- Computer Systems Engineering
- Software Engineering

The course listings below specify which courses may be taken to fulfill the specialty track course requirements.

**Specialization in Communications, DSP and Networking**

This area of specialization prepares students for research, development, and implementation in the area of communication system development where competency is developed in topics from network design, signal processing, and high speed implementation of digital systems.

- ENCE 3310 Data Communications
- ENCE 4100 High Speed Digital Design
- ENCE 4300 Mixed Signal Design & Testing
- ENCE 4311 Image Processing & Application
- ENCE 4361 Wireless Comm and Mobile Networks
- ENEE 3130 Principles of Comm Systems
- ENEE 3141 Digital Communications
- ENEE 3660 Communications Systems Design
- ENEE 3665 Intro Telecom Systems
- ENEE 3670 Intro to DSP
- ENEE 3150 Communication Systems Lab
- ENEE 4325 Data & Computer Communications
- ENEE 4360 Digital & Space Communications
- ENEE 4410 Adv Signal Processing & Comm
- ENEE 4415 Advanced DSP
- ENEE 4620 Adv Optical Fiber Comm
- ENCE 4800 Advanced Topics (CPE) (appropriate topics)

**Robotics, Embedded Systems and Instrumentation**

This area of specialization prepares students for research, development, and implementation in the area of robotic and embedded systems where competency is developed in topics from controls, system design, and algorithm implementation.

- ENCE 3231 Embedded Microprocessors
- ENCE 4300 Mixed Signal Design & Testing
- ENCE 4341 Distributed Systems
- ENEE 4421 Robot Computer Vision
- ENCE 4550 Dig. Testing & Testable Design
ENCE 4581 Adv Robotics Automation and MI
ENCE 4600 HDL Modelling & Synthesis
ENCE 4800 Advanced Topics (CPE) (appropriate topics)
ENGR 3610 Engineering Analysis
ENGR 3721 Controls
ENGR 3730 Robotics
ENGR 4745 Advanced Nonlinear Control Systems
COMP 3501 Intro to Artificial Intelligence
COMP 3801 Introduction Computer Graphics

Computer Systems Engineering

This area of specialization prepares students for research, development, and implementation in the area of computer systems where competency is developed in topics from hardware design, software design and architectural implementation.

ENCE 3231 Embedded Microprocessors
ENCE 3501 VLSI Design
ENCE 4341 Distributed Systems
ENCE 4501 Adv. VLSI Design
ENCE 4550 Dig. Testing & Testable Design
ENCE 4600 HDL Modelling & Synthesis
ENCE 4800 Advanced Topics (CPE) (appropriate topics)
COMP 3352 Elements of Compiler Design
COMP 3361 Operating Systems I
COMP 3694 Advanced Computer Architecture

Software Engineering

This area of specialization prepares students for research, development, and implementation in the area of software engineering where competency is developed in topics from language development, algorithmic implementation, and information management.

ENCE 3231 Embedded Microprocessors
ENCE 4341 Distributed Systems
ENCE 4800 Advanced Topics (CPE) (appropriate topics)
COMP 3371 Advanced Data Structures and Algorithms
COMP 3381 Software Engineering I
COMP 3351 Programming Languages
COMP 3421 Database Organization and Management I
COMP 3422 Database Organization and Management II
COMP 4573 Scientific Computation

Electrical Engineering

The MS (EE) program offers three areas of specialization:

• Electromagnetics and Optical Communications
• Signal Processing and Communications
• Systems and Controls

The course listings below specify which courses may be taken to fulfill the specialty track course requirements.

Specialization in Electromagnetics and Optical Communications

This area of specialization prepares students for research, development and design of devices and systems that operate using wave theory: laser, optics and light wave devices; electromagnetic theory, waveguides and antennas.

ENCE 3030 Optoelectronics
ENCE 3035 Photonics
ENCE 3620 Optical Fiber Communications
Specialization in Signal Processing and Communications

This specialization prepares students for research, development and design of information transmission, reception, and processing systems. Courses provide breadth with respect to algorithms for the processing of signals and information. Breadth is also provided in the study of alternate communication (information transfer over space and terrestrial channels) techniques and specific applications in image and speech processing methods. Depth is provided through several courses in specific areas.

Specialization in Systems and Controls

This area of specialization focuses on the theory and design of modern analog and digital control systems to include nonlinear analysis methods, adaptive control, control of stochastic systems and control based on information theoretic concepts with a specific focus on robotics system design available.
Mechanical Engineering

The MS (ME) program offers three areas of specialization:

• Structure and Behavior of Materials
• Fluid Mechanics and Heat Transfer
• Mechanical Design and Analysis/Robotics

The following course listings specify which courses may be taken to fulfill the specialty track course requirement.

Specialization in Structure and Behavior of Materials

This area of concentration prepares students for research and development work in areas of technology which are currently materials limited. This specialization develops the skills to successfully couple materials with new properties to demanding design applications. Courses provide breadth with respect to materials types (composites, ceramics, semiconductors, polymers) and characterization techniques (acoustic emission, x-ray diffraction, surface analysis).

ENME 3230 Intro to Nondestructive Eval
ENME 3540 Intro to Continuum Mechanics
ENME 4360 Advanced Elasticity
ENME 4370 Plasticity
ENME 4800 Adv Topics (ME)
ENEE 4040 Semiconductor Devices
ENGR 3630 Finite Element Methods
MTSC 3110 Thermodynamics of Solids
MTSC 3210 Mech Behavior of Materials
MTSC 4130 Intro to Surface Science
MTSC 4140 Surface Analysis
MTSC 4150 Diffraction & Structure I
MTSC 4155 Diffraction & Structure II
MTSC 4210 Composite Materials I
MTSC 4215 Composite Materials II
MTSC 4230 Polymer Science I
MTSC 4235 Polymer Science II
MTSC 4250 Struct & Properties of Ceramics I
MTSC 4255 Struct & Properties of Ceramics II
MTSC 4310 Design w/ Materials w/ Var Props
MTSC 4800 Advanced Topics (ME) (appropriate topics)

Specialization in Fluid Mechanics and Heat Transfer

This area of concentration prepares students for the research and design of thermal/fluid systems (i.e. ventilation, engines, aerosols, atomization and novel process design). This specialization provides the students with a thorough foundation in the principles of thermodynamics, fluid mechanics, or heat & mass transfer. Courses provide this foundation through analytical, numerical and experimental methods. Students may choose to master one particular subject area within this specialization or take courses in all three areas in order to master a particular system, process, or engine.

ENGR 3630 Finite Element Methods
ENME 3540 Intro to Continuum Mechanics
ENME 3651 Computational Fluid Dynamics
ENME 3731 Adv Engr Thermodynamics
ENME 3820 Special Topics (typical offerings):
  a) Experimental Methods in Heat Transfer and Fluid Mechanics
  b) Heating, Ventilation and Air Conditioning
  c) Analytical Methods in Heat Transfer and Fluid Flow
ENME 4610 Inviscid Flow
Specialization in Mechanical Design and Analysis/Robotics

This area of concentration prepares students for the design and analysis of mechanical components. This specialization covers the design and analysis of both rigid and dynamic structures. Students may choose to emphasize one of several areas within this specialization. These areas include: mechanisms and machinery; design methods; and structural analysis.

ENGR 3630 Finite Element Methods
ENGR 3730 Robotics
ENGR 3750 Energy Conversion & Power Syst
ENGR 4620 Optimization in Design
ENME 3230 Intro to Nondestructive Eval
ENME 3540 Intro to Continuum Mechanics
ENME 3545 Mechanisms
ENME 3550 Mechanical Vibrations
ENME 3555 Advanced Dynamics
ENME 3560 Advanced Mechanisms & Machinery
ENME 4800 Advanced Topics (ME) (appropriate topics)
MTSC 3210 Mech Behavior of Materials
MTSC 4210 Composite Materials I
MTSC 4215 Composite Materials II
MTSC 4310 Design w/Materials w/Var Props

Joint Master of Science in
COMPUTER SCIENCE AND ENGINEERING

Engineering is a field highly dependent upon computer technology for numerous applications such as: simulations, data acquisition, information processing, modeling, programming, data reduction, data analysis, engineering design, “what ifs,” presentations, control and graphics, to mention only a few of the more common ones. As a result of this dependency, a strong interest in combining both an advanced degree in engineering and in computer science has led to the development of a joint degree, a Masters of Science in Computer Science and Engineering (MS CS/E). Dual masters degrees in Computer Science and Engineering would require 90 quarter hours. The total hours for this joint degree are only 60 quarter hours. By reducing the number of hours and building flexibility into the degree program, this joint degree is more desirable and attainable than the dual degrees. This joint degree offers the opportunity to concentrate on both the key engineering areas of interest and to obtain a solid set of core knowledge in computer science. Most probably, the typical person seeking this degree will be an engineer who is highly interested in computer science. Such individuals are involved in the intimate use and integration of computers in their everyday work.

ADMISSION TO THE PROGRAM

This program is designed primarily for engineers, hence in normal circumstances a bachelor of science degree from an ABET-accredited program is required for admission to the MS (CS/E) program. However persons without an engineering degree (physicists, computer scientists, chemists, engineering technologists, material scientists, mathematicians, etc.) may be accepted provided they give evidence of certain basic knowledge. In any case, students without these basic prerequisites may be required to achieve that background as provisional candidates before being admitted as regular students. Specifically, the following background would be expected:

All students should possess mathematical skills to include:
• Higher Mathematics through Differential Equations
• Probability and Statistics
• Discrete Mathematics

All students should possess the following Computer Science background:

• A basic introduction to Computer Science including knowledge in a programming language, preferably C/C++
• Logical Design of Digital Computers
• Introduction to Algorithms and Data Structures

Students intending to focus on Computer Engineering:

• Microprocessors
• Basic and Advanced Digital Design
• Digital Communications Systems and DSP
• Computer/Data Communications and Networks

Students intending to focus on Electrical Engineering:

• Circuit Analysis and Electronics
• Physical Electronics
• Electromagnetics
• Signals, Systems and Communications

Students intending to focus on Mechanical Engineering:

• Mechanics
• Thermodynamics
• Fluid Mechanics
• Materials Science

Students intending to focus on Materials Engineering:

• Materials Science
• Physical Chemistry
• Physics of Solids
• Mechanical Behavior of Materials

Students not possessing this background may be admitted as provisional students while they acquire the necessary prerequisite undergraduate courses. Prerequisite courses with catalog numbers below 3000 do not count towards the requisite 60 quarter hours needed for the degree. In addition, there is a limit to the number of 3000 level quarter hours that can be allowed towards the degree. Candidates who did not earn a 3.0/4.0 GPA may be required to pass a competency examination on the appropriate prerequisites.

PROGRAM REQUIREMENTS

Minimum Credit Requirements

Every candidate for the MS (CS/E) degree must complete 60 quarter hours of credit, at least 51 of which must be completed at the University of Denver.

Program Structure

Candidates for the degree of Master of Science (Computer Science and Engineering) must choose either the Thesis or Non-Thesis Option. This choice may be made at any time, although a delay in declaration may impact the completion date. Students who are GTAs or who receive financial support from a University research grant as graduate research assistants (GRAs) are required to elect the thesis option.

Non-Thesis Option: It is anticipated that non-thesis students will take more than two years to complete the requirements. The basic structure of the minimum 60 quarter hours for the non-thesis option is as follows:
Computer Science Core (required courses) 20 QH
Computer Science Electives 8 QH
Engineering Core 18 QH
Engineering Electives 10 QH
Capstone Project 4 QH
60 QH

The project should integrate engineering and computer science.

Thesis Option: The thesis option is required for all Graduate Research Assistants (GRAs) and Graduate Teaching Assistants (GTAs). The basic structure of the minimum 60 quarter hours for the thesis option is as follows:

Computer Science Core 20 QH
Computer Science Electives 4 QH
Engineering Core 18 QH
Engineering Electives 6 QH
Thesis 12 QH
60 QH

The thesis should integrate engineering and computer science.

Computer Science Core

Each candidate must take the following computer science core courses:

• COMP 3200 - Discrete Structures
• COMP 3351 - Programming Languages
• COMP 3361 - Operating Systems
• COMP 4371 - Advanced Data Structures
• COMP 4694 - Advanced Computer Architectures

Computer Science Electives

Must be completed in courses with COMP or MATH prefixes at the 3000 level or above.

Engineering Core

Twenty quarter hours of courses with ENGR, ENME, ENCE, ENEE or MTSC prefixes, at least two at the 4000 level. At least 12 qtr. hrs must be from one discipline (minimum 6 hours).

Engineering Electives

The engineering electives may be selected from courses numbered 3000 and above in the departments of Engineering, Physics, Biology, or Chemistry in consultation with the student’s advisor, who ensures that the program is academically sound.

Engineering Seminar - GRA/GTA Requirement

All MS(CS/E) Graduate Research and Teaching Assistants (GRAs and GTAs) are required to attend the Engineering Seminar even if not formally enrolled in the class.

Joint Master of Science in MANAGEMENT AND ENGINEERING

The Master of Science in Management and Engineering is a unique joint degree offered by the Daniels College of Business and the Department of Engineering. It is designed primarily for the professional engineer who is in mid-career (5 to 12 years post BS). Many engineers advance to leadership positions within their businesses. They are designated team or group leaders or promoted to section, branch or division heads. In these roles, they are called upon to exercise managerial skills that often have not been fully developed. Furthermore with technology constantly undergoing rapid change, skills acquired in undergraduate education may be in need of upgrading and expansion. The purpose of this program is to serve the engineering profession and the Colorado industrial community through advanced study in both
management and engineering, thus meeting both needs in one comprehensive program. The program prepares its students for industrial advancement.

**ADMISSION TO THE PROGRAM**

A bachelor of science degree in an ABET (or ECPD) accredited engineering program or closely related field is required for admission to this program. In addition, as part of the graduate admission procedure for the University of Denver, the applicant must submit scores from either the Graduate Record Examination (GRE) general test or the Graduate Management Admissions Test (GMAT). Those students whose backgrounds differ significantly from that ordinarily expected of traditional engineering graduates may be required to complete prerequisite undergraduate courses; such courses are not considered part of the 28 engineering credit-hours requirement for the degree. A competency examination may be required of entering students who do not possess a 3.0 GPA or a BS from an ABET (or ECPD) accredited institution. Students with BS degrees in physics, mathematics, computer science, materials science, engineering technology, engineering physics or similar bachelor of science degrees may also be admitted. Graduate Teaching Assistantships are not available for students wishing to pursue this degree.

Consideration for admission is based on the following:

- completed application ($50 application fee)
- proof of a bachelor’s degree from a regionally accredited college or university
- relevant work experience
- results from the Graduate Management Admission Test (GMAT) or Graduate Record Exam (GRE)
- two letters of recommendation
- complete responses to the essay questions
- score of 570 or better on the Test of English as a Foreign Language (TOEFL) for international applicants whose native language is not English (540 for possible conditional acceptance)
- managerial and leadership potential
- diversity

Completed applications should be sent to:

Daniels College of Business  
2101 S. University Blvd.  
Room 225  
Denver, CO 80208  
(303) 871-3416 or 1-800-622-4723

The program currently employs a rolling deadline and students are admitted in the fall, winter, and spring quarters. To be certain of acceptance to a particular quarter, a completed application should be received by the Department of Engineering at least 45 days before the start of the quarter.

**PROGRAM REQUIREMENTS**

**Minimum Credit Requirements**

Every candidate for the MS in Management and Engineering degree must complete 68 quarter hours of credit, at least 51 of which must be completed at the University of Denver.

**Program Structure**

Candidates for the degree of Master of Science in Management and Engineering must complete the following:

**Management Core**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>QH</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUS 4100</td>
<td>Values-Based Leadership</td>
<td>4</td>
</tr>
<tr>
<td>BUS 4200</td>
<td>The 21st Century Professional</td>
<td>4</td>
</tr>
<tr>
<td>BUS 4300</td>
<td>Global Information Economy</td>
<td>4</td>
</tr>
<tr>
<td>MBA 4290</td>
<td>Business Strategy (cf. note below)</td>
<td>4</td>
</tr>
</tbody>
</table>

**Business Electives (with advisor approval)** (cf. note below) 18 QH

**Total Graduate Management Hours** 34 QH
Note: Business “Foundations” courses may not be used to complete any hour requirements, but must be taken if they are prerequisites to other courses which are to be applied to the degree. Some students may be able to test out of relevant “foundations” courses. For example, a student specializing in Finance may be required to take FIN 3900, but cannot apply the hours to the degree, or may be able to test out of FIN 3900, and to proceed directly into applicable courses.

<table>
<thead>
<tr>
<th>Course</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration Coursework</td>
<td>15 QH</td>
</tr>
<tr>
<td>Technical Electives</td>
<td>15 QH</td>
</tr>
<tr>
<td>Advanced Project</td>
<td>4 QH</td>
</tr>
<tr>
<td>Total Engineering Hours</td>
<td>34 QH</td>
</tr>
<tr>
<td>Internship</td>
<td>1-4 QH</td>
</tr>
</tbody>
</table>

The Internship may be waived with advisor approval.

A maximum of 15 QH may be transferred from another approved institution or earned as a Special Status student and count towards this degree.

**Management Core**

The Management Core courses mirror the cross-functional involvement found in business decision-making. Instead of separate courses for each discipline, there are three courses presenting business fundamentals, such as accounting, financial management, marketing, statistics and current business issues in an interrelated format providing a comprehensive view of business the way it actually operates, and one capstone course which builds upon these fundamentals and on the student's chosen specialization.

**Management Electives**

18 quarter hours from the Daniels College of Business, selected with the aid of an advisor from the College.

**Engineering Core**

Fifteen quarter hours from 3000 or 4000 level courses with ENGR, ENME, ENCE, ENEE or MTSC prefixes, with a minimum of three courses at the 4000 level. These courses are selected from the regular offerings of the Department of Engineering in consultation with an Engineering advisor to suit the particular interests of the professional. These courses provide depth in the engineering portion of the program.

**Technical Electives**

Fifteen quarter hours from 3000 or 4000 level courses (with a minimum of two courses at the 4000 level) with ENGR, ENME, ENCE, ENEE, MTSC, COMP, PHYS, CHEM, BIOL, or MATH prefixes. This requirement is designed to provide flexibility to the technical portion of the degree by permitting students to select broadening courses from other non-engineering disciplines, if desired.

**Advanced Project**

All students are required to complete an integrative advanced project (ENGR 4930) which combines aspects of both Engineering and Management.

**Doctor of Philosophy in ENGINEERING**

The Ph.D. degree in Engineering is designed to prepare the student for research and development work in computer, electrical or mechanical engineering. The Ph.D. program provides the rigorous preparation required for applied research professionals in government, industry and other technology-based areas, as well as the intellectual depth required for academic careers.

**ADMISSION TO THE PROGRAM**

Students with a Master’s degree in Computer, Electrical, Mechanical Engineering or closely related areas may apply for the Ph.D. program of study in Engineering. Admission with only a Bachelor of Science in this field is also possible, but students with only a BS degree are strongly encouraged to enroll first in the MS (CPE, EE, or ME) programs. Admission to the Ph.D. program in Engineering is based on a review of the application and associated references. Nominally, a grade point average of at least 3.0 is required. All graduate engineering courses presuppose mastery of the subject matter of a modern ABET accredited
curriculum in Engineering. Students with a Bachelor of Science in other engineering or related science fields and students with a BSCPE, BSEE, BSME who have not taken graduate academic work for some time may be required to complete preparatory courses that are prerequisites for the core courses of the three engineering concentrations on which the qualifying exams are based. These courses carry no credit toward the graduate degree.

**Program Structure**

Students entering the Ph.D. in Engineering degree program may specialize in Computer Engineering, Electrical Engineering or Mechanical Engineering. The minimum credit requirements are different for individuals entering the program with a closely related Master’s degree and for those entering with a Bachelor’s only. All requirements for the degree must be completed within 8 years from admission to candidacy.

**PROGRAM REQUIREMENTS**

**Qualifying Examination**

First and foremost, each student admitted to the Engineering Ph.D. program must pass the Qualifying Exam to obtain candidacy or official entrance into the doctoral program. The Qualifying Exam is usually taken at the end of spring quarter after the first full year of academic study (3 quarters of Ph.D. study). However, students enrolled in one of the engineering Master’s programs may opt to take the Qualifying Exam at the end of the spring quarter of the second year of their MS program. Prior to taking this examination, a student must identify a faculty member who has indicated that he/she is willing to supervise the student’s research.

The purpose of the Qualifying Exam is to determine whether the student has the necessary foundations to undertake doctoral studies.

The Qualifying Exam will take place over a five hour, uninterrupted period, for example: 7:30 AM - 12:30 PM. Individual subject tests will be designed to take one hour, but each student will be given the entire exam at the start of the examination period and expected to regulate the time accordingly. Students who do not pass a topic area will be allowed to retake that subject area once. In unusual circumstances students may petition to retake a subject area a second time, but must have their advisor’s written support for the petition.

Ph.D. students seeking a concentration in **Computer Engineering** must demonstrate competence in five of the seven fundamental areas listed below. Each topic will be graded separately. To pass the Qualifying Exam the student must obtain a passing score in all five subject areas. Well in advance of the exam, students will submit a request to take the Qualifying Exam and list the five areas on which they seek to be tested. The professors who teach these courses will make available a list of topics they feel are needed to demonstrate competency so that the student can properly prepare for the exam.

- Advanced Digital Design
- Computer Architecture and Organization
- VLSI Design
- Circuits and Electronics
- Programming Structure and Language
- Microprocessor Systems
- Computer Networks

Ph.D. students seeking a concentration in **Electrical Engineering** must demonstrate competence in five of the seven fundamental areas listed below. Each topic will be graded separately. To pass the Qualifying Exam the student must obtain a passing score in all five subject areas. Well in advance of the exam, students will submit a request to take the Qualifying Exam and list the five areas on which they seek to be tested. The professors who teach these courses will make available a list of topics they feel are needed to demonstrate competency so that the student can properly prepare for the exam.

- EM Fields I and II
- Circuits and Electronics
- Signals and Systems
Ph.D. students seeking a concentration in Mechanical Engineering must demonstrate competency in five of the seven fundamental areas listed below. Each topic will be graded separately. To pass the Qualifying Exam the student must obtain a passing score in all five subject areas. Well in advance of the exam, students will submit a request to take the Qualifying Exam and list the five areas on which they seek to be tested. The professors who teach these courses will make available a list of topics they feel are needed to demonstrate competency so that the student can properly prepare for the exam.

Thermodynamics (2nd quarter equivalent)
Introduction to Fluids
Introduction to Heat transfer
Engineering Mechanics (3rd quarter equivalent)
Machine Design
Materials Science (2nd quarter equivalent)
Mechanics of Materials

Minimum Credit Requirements

Students with a Bachelor's Degree only
For students entering with a Bachelor's degree 90 QH of course work are required, 72 of which must be completed at the University of Denver. A minimum of 48 QH must be at the 4000 level and may include as many dissertation research hours (Independent Research and Independent Study) as considered appropriate by the student's advisor. The student with his or her advisor will devise an appropriate program of study in a major, a minor, and advanced mathematics. Prior to completion of the comprehensive exam, the program of study must also be approved by the student's Ph.D. committee. The major will consist of 15 QH of course work (with a minimum of three 4000 level courses, excluding independent research). 9 QH of course work (excluding independent research) are required to establish a minor. The minor must be in engineering or related areas (e.g., Mathematics, Computer Science, Physics, Chemistry or Cognitive Sciences). Further, a 3 QH advanced mathematics requirement must be met. Advanced mathematics courses at the 3000 or higher level are selected with the prior approval of the student's advisor. In addition three quarter hours of Engineering Seminar are required.

Students with a closely related Master's Degree
If a student is admitted with a closely related Master's degree, a minimum of 45 QH is required, 36 of which must be completed at the University of Denver. The student with his or her advisor will devise an appropriate program consisting of a minimum of 36 QH at the 4000 level, which may include as many dissertation research hours (Independent Research and Independent Study) as considered appropriate by the student's advisor. In addition three quarter hours of Engineering Seminar are required. Prior to completion of the comprehensive exam, the program of study must also be approved by the student's Ph.D. committee.

Comprehensive Examination
Generally within three years of attaining candidacy, the student should schedule and take the comprehensive examination. This oral examination will be attended by a minimum of three faculty members, preferably the student's entire Ph.D. committee, with the student's advisor acting as chair. The student will be expected to make a 20 to 30 minute concise presentation on his/her dissertation topic. The presentation will highlight previous work in this area, demonstrate a need for the research, and explain how the research will contribute to the advancement of the area. The student will also present completed work and results, anticipated work and results, and a detailed plan for project completion. In addition, the student will be expected to answer general fundamental questions in the area of his/her concentration and detailed questions in the area of the student's graduate course work. The examination can be retaken only once.

Dissertation
The student is required to complete and defend a dissertation of publishable quality based on the student's original research. The dissertation must be completed in written form in accordance with university Graduate School guidelines. A summary of the dissertation must be presented in a public seminar and subsequently
defended by the student in the final oral examination. The examining committee will consist of the student’s entire Ph.D. committee.

**Residence Requirement**

One year of full-time graduate work and two consecutive years of part-time graduate work satisfy the minimum residency requirement at the University of Denver.

**Ph.D. Committee**

The Ph.D. committee will consist of five faculty members. Three faculty members must be from within the student’s specialty area; these can include the student’s advisor, other faculty in that degree program and, if necessary, off campus experts. Finally, the committee chair must be a faculty member outside the department of engineering.

**Suggested Courses**

It is strongly recommended that courses used to fulfill the remainder of the required quarter hour requirements be selected from among those listed below and those listed under the qualifying exam above, in consultation with the student’s advisor.

ENCE 3100 Advanced Digital Systems Design  
ENCE 3220 Microprocessor Systems II  
ENCE 3241 Computer Organization  
ENCE 3310 Data Communications  
ENCE 3501 VLSI Design  
ENCE 3830 Special Topics in Image Processing  
ENCE 4100 High Speed Digital Design  
ENCE 4300 Mixed Signal Design & Testing  
ENCE 4341 Distributed Systems  
ENCE 4421 Robot Computer Vision  
ENCE 4501 Adv. VLSI Design  
ENCE 4550 Dig. Testing & Testable Design  
ENCE 4581 Adv Robotics Automation & MI  
ENCE 4600 HDL Modelling & Synthesis  
ENCE 4800 Advanced Topics (CPE) ENCE 4991 Independent Study  
ENCE 4995 Thesis Research  
ENEE 3011 Physical Electronics  
ENEE 3020 Integrated Circuit Design  
ENEE 3030 Optoelectronics  
ENEE 3035 Photonics  
ENEE 3040 Semiconductor Microtechnology  
ENEE 3111 Signals and Systems  
ENEE 3130 Principles of Comm Systems  
ENEE 3150 Communication Systems Lab  
ENEE 3546 CAD of Microwave Circuits  
ENEE 3620 Optical Fiber Communications  
ENEE 3630 Antennas  
ENEE 3660 Communication Systems Design  
ENEE 3665 Introduction to Telecomm Systems  
ENEE 3670 Introduction to DSP  
ENEE 3810 Special Topics (EE)  
ENEE 4010 Quantum Optics & Electronics  
ENEE 4020 Lasers & Non-linear Optics  
ENEE 4040 Semiconductor Devices  
ENEE 4080 Physical Optics  
ENEE 4300 Noise in Optics & Electronics  
ENEE 4310 Information Theory & Coding  
ENEE 4325 Data & Computer Communications  
ENEE 4360 Digital & Space Communications  
ENEE 4410 Adv Signal Processing & Comm  
ENEE 4415 Advanced DSP
ENEE 4425 Image Processing
ENEE 4450 Speech Processing
ENEE 4610 Advanced Electromagnetics
ENEE 4620 Adv Optical Fiber Comm
ENEE 4670 Modern & Digital Control Systems
ENEE 4720 Modern & Digital Control Sys
ENEE 4800 Special Topics (EE)
ENEE 4991 Independent Study
ENEE 4955 Thesis Research
ENGR 3610 Engineering Analysis
ENGR 3630 Finite Element Methods
ENGR 3720 Controls
ENGR 3730 Robotics
ENGR 4620 Optimization in Design
ENGR 4745 Adv Nonlinear Control Systems
ENME 5995 Independent Research
ENME 3230 Intro to Nondestructive Eval
ENME 3511 Machine Design
ENME 3540 Introduction to Continuum Mechanics
ENME 3545 Mechanisms
ENME 3550 Mechanical Vibrations
ENME 3555 Advanced Dynamics
ENME 3560 Adv Mechanisms & Machinery
ENME 3820 Special Topics (ME)
ENME 3850 Thermal Systems Design
ENME 3860 Air Pollution
ENME 4360 Advanced Elasticity
ENME 4370 Plasticity
ENME 4610 Inviscid Flow
ENME 4630 Viscous Flow
ENME 4640 Compressible Flow
ENME 4700 Conductive Heat Transfer
ENME 4710 Convective Heat Transfer
ENME 4720 Radiative Heat Transfer
ENME 4800 Special Topics (ME)
ENME 4991 Independent Study
ENME 4995 Independent Research
MTSC 3110 Thermodynamics of Solids
MTSC 3210 Mech Behavior of Materials
MTSC 4130 Intro to Surface Science
MTSC 4140 Surface Analysis
MTSC 4150 Diffraction & Structure I
MTSC 4155 Diffraction & Structure II
MTSC 4210 Composite Materials I
MTSC 4215 Composite Materials II
MTSC 4230 Polymer Science I
MTSC 4235 Polymer Science II
MTSC 4250 Struct & Props of Ceramics I
MTSC 4255 Struct & Props of Ceramics II
MTSC 4310 Design w/ Materials w/ Var Props
CHEM 3620 Physical Chemistry II
CHEM 3640 Chemical Energetics and Dynamics
PHYS 3111, 3112, 3113 Quantum Physics I, II, III
PHYS 3411, 3412, 3413 Solid State Physics I, II, III
PHYS 4111, 4112, 4113 Quantum Mechanics I, II, III
PHYS 4411, 4412, 4413 Advanced Dynamics I, II, III
PHYS 4551, 4552, 4553 Mathematical Physics I, II, III
PHYS 4811, 4812, 4813 Statistical Mechanics I, II, III
MATH 3080 Introduction to Probability
MATH 3180 Mathematical Statistics
MATH 3651 Differential Equations & Applied Mathematics I
MATH 3652 Differential Equations & Applied Mathematics II
MATH 3851, 3852 Introduction to Functions of Complex Variables I, II
COMP 3361, 3362, 3363 Operating Systems I, II, III
COMP 3371 Advanced Data Structures and Algorithms
COMP 4573 Scientific Computation

**Seminar Requirement**

All students are required to register for at least three quarter hours of Engineering Seminar (ENGR 4900); six quarter hours are required if the student is entering with a BS degree. In addition, all students are required to attend all Engineering Seminars whether or not they have registered for seminar.

**INTERDISCIPLINARY Ph.D. PROGRAM**

The program offers opportunities for students to petition to the Engineering Department if they wish to follow special advanced programs of study in Engineering. In such a case, the petition must have the sponsorship of three faculty members, at least one of whom shall be from the Department of Engineering. When a significant amount of work is to be taken in another division or department, one faculty member from each division/school or department must act as a sponsor.

**Doctor of Philosophy in MATERIALS SCIENCE**

The Ph.D. degree in materials science is designed to prepare the student for research and development work in the materials field. The program is multidisciplinary and involves the Departments of Physics, Chemistry, and Engineering, with Engineering as the administering department. The program reflects this multidisciplinary nature by providing a thorough grounding in each of the basic disciplines of the field. Depth in specialized areas is achieved through the research interests of faculty in each of the participating departments. These faculty members constitute the Materials Science Faculty Group, which is responsible for implementing and administering the program.

With an increasing number of technological fields becoming materials limited in various ways, the program seeks to prepare students to meet the challenges of property improvement and new materials development, with a broad-based curriculum which stresses fundamentals.

**ADMISSION TO THE PROGRAM**

A master of science in materials science or closely related field (physics, metallurgy, engineering, chemistry) is usually required for admission. Admission with only a bachelor of science degree in these fields is also possible in limited cases, but students with only a BS degree are strongly encouraged to first enroll in either the MSME (structure and behavior of materials specialization) or the MSEE (electromagnetics, quantum optics, semiconductors specialization). Applicants must submit scores from the Graduate Record Examination (GRE) General Test. Normally, a grade point average (GPA) of at least 3.0 on a 4.0 scale is required.

Students whose background differs significantly from that ordinarily expected of materials science students can be admitted on a provisional basis. They will usually be required to complete preparatory courses that are prerequisites for the materials science core courses on which the qualifying exam is based (see below). Such courses are not considered part of the 90 quarter hour requirement for the degree.

**MINIMUM PROGRAM REQUIREMENTS**

**Qualifying Examination**

All students admitted to the program are required to take the qualifying examination as soon as they have sufficient preparation in the subject areas of the exam—normally within the first two academic years of study. The subject areas are based on the material covered in the following courses:

- ENGR 3630 Finite Element Methods
- MTSC 3110 Thermodynamics of Solids
- MTSC 3210 Mechanical Behavior of Materials
- MTSC 3430 Diffraction and Structure I
PHYS 3411, 3412 Solid State Physics I, II  
CHEM 3620 Physical Chemistry II  
or  
CHEM 3311 Molecular Structure and Energetics I

The exam is usually given at the end of spring quarter each year. Students must pass the exam to be admitted to candidacy for the Ph.D. degree. The exam may be retaken once.

**Minimum Credit Requirements**

If the student is admitted with a closely related master’s degree, a minimum of 45 quarter hours are required, 36 of which must be completed at the University of Denver.

Students admitted with a bachelor’s degree are required to complete 90 quarter hours, 72 of which must be completed at the University of Denver. A minimum of 36 quarter hours (48 for students required to complete 90 hours) must be at the 4000 level and may include as many thesis research hours (Independent Research, MTSC 5991 and Independent Study, MTSC 5995) as considered appropriate by the student’s advisor.

**Advisor**

For the first academic year, the advisor for all students will be the materials science program coordinator. At the end of the first academic year, it is the student’s responsibility to choose an advisor from among the materials faculty group who will help plan the student’s future course work, thesis work, and financial support. Without an advisor, the student cannot continue in the program.

**Suggested Courses**

It is strongly recommended that courses for fulfilling the remainder of the required quarter hour requirements be selected from among those listed below and those listed under the qualifying exam above, in consultation with the student’s advisor.

MTSC 4130 Introduction to Surface Science  
MTSC 4140 Surface Analysis  
MTSC 4150 Diffraction & Structure I  
MTSC 4155 Diffraction & Structure II  
MTSC 4210 Composite Materials I  
MTSC 4215 Composite Materials II  
MTSC 4230 Polymer Science I  
MTSC 4235 Polymer Science II  
MTSC 4250 Struct & Props of Ceramics I  
MTSC 4255 Struct & Props of Ceramics II  
MTSC 4310 Design w/ Materials w/ Variable Props  
MTSC 4800 Advanced Topics  
MTSC 4900 Seminar  
MTSC 5991 Independent Study  
MTSC 5995 Independent Research  
ENME 3230 Intro to Nondestructive Eval  
ENME 3540 Intro to Continuum Mechanics  
ENME 4020 Adv Finite Element Analysis  
ENME 4360 Advanced Elasticity  
ENME 4370 Plasticity  
ENCE 3501 VLSI Design  
ENEE 3011 Physical Electronics  
ENEE 3030 Optoelectronics  
ENEE 3035 Photonics  
ENEE 3040 Semiconductor Microtechnology  
ENEE 3050 Plasma Processing of Materials  
ENEE 4010 Quantum Optics and Electronics  
ENEE 4080 Physical Optics  
ENGR 3610 Engineering Analysis  
CHEM 3320, 3330 Molecular Structure and Energetics II, III  
PHYS 3111, 3112, 3113 Quantum Physics I, II, III  
PHYS 3841, 3842 Thermal Physics I and II
Materials Science Seminar Requirement
All students are required to register for at least three quarter hours of Materials Science Seminar (MTSC 4900); six quarter hours are required if the student is entering with a BS degree. In addition, all students are required to attend all Materials Science Seminars whether or not they have registered for seminar.

Comprehensive Examination Requirement
Generally within two years of attaining candidacy, the student must schedule and take the comprehensive examination. This oral examination will be attended by a minimum of three materials group faculty members with a member other than the student's advisor acting as chair. The student will be expected to complete the following:
• Make a 20–30 minute concise presentation on his/her thesis topic including approach, proposed experiments, theoretical work, anticipated results, results to date.
• Answer general fundamental questions in any area of materials science, and answer detailed questions in the area of the student's graduate course work. The examination can be retaken once and must be completed within three years of achieving candidacy.

Thesis Requirement
The student is required to complete and defend a thesis of publishable quality based on the student’s original research. The thesis must be completed in written form in accordance with university guidelines. A summary of the thesis must be presented in a public seminar and subsequently defended by the student in the final oral examination. The examining committee will be constituted in accordance with University policy. All requirements for the degree must be completed within 8 years from admission to candidacy.

COURSE DESCRIPTIONS
Candidates should note that not all of the engineering courses listed below are offered each year. They should check the University’s schedule of classes or inquire at the engineering department (303-871-2102) to determine which classes are being offered in a given academic year.

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 3231 Embedded Microprocessor Systems (3 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.)

ENCE 3310 Data Communications (3 qtr. hrs.)
(Co-listed with ENEE 4325) Introduction to OSI (Open Systems Interconnect model) for communications systems. Fundamental operations of data communication devices. Modems, control units, multiplexors, front-end processors, error checking, compression, port arbitration on Ethernet hubs.

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 CMOS 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 be taken more than once. Prerequisite: varies with offering.

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 4300 Mixed Signal Design & Testing (3 qtr. hrs.)
Design, analysis, and implementation of testable mixed-signal systems. The test specification process and design for test (DfT) 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 4311 Image Processing & Application (3 qtr. hrs.)
Covers methods for coding, storing, and filtering images via digital computer; sampling, understanding, and pattern recognition. Project.

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 4361 Wireless Comm & Mobile Netw’ks (3 qtr. hrs.)
Introduces the principles of wireless data communications. State-of-the-art network architectures will be introduced. Covers an overview of wireless networks, architectures of existing mobile data networks, and mobility gateway technologies. 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 Adv. 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. Prerequisite: ENCE 3501 or permission of instructor.
ENCE 4550 Dig. Testing & Testable Design (3 qtr. hrs.)

ENCE 4581 Adv Robotics Automation & MI (3 qtr. hrs.)
Advanced foundations and principles of robotic manipulation are studied. Studies include advanced robot motion planning task level programming and architectures for building perception and systems for intelligent robots. Autonomous robot navigation and obstacle avoidance are studied. Topics include computational models of objects and motion, the mechanics of robotic manipulators, the structure of manipulator control systems, planning and programming of robot actions. Components of mobile robots, perception, mechanism, planning, and architecture; detailed case studies of existing systems. Project.

ENCE 4600 HDL Modelling & Synthesis (3 qtr. hrs.)
Introduction to Hardware Design Language (HDL). Language syntax and synthesis. Applications related to digital system implementation are developed. Project.

ENCE 4800 Adv Topics (CPE) (1-5 qtr. hrs.)
Various topics in Computer Engineering as announced. May be taken more than once. Prerequisite: varies with offering.

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

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

Electrical Engineering

ENCE 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).

ENCE 3030 Optoelectronics (3 qtr. hrs.)
The active and passive optical elements: includes principles of light, optical sources (LED, LASER, Fiber LASER), optical fibers, photodetectors (APD, PIN, MSM) and practical optical transmitters and receivers. Laboratory.

ENCE 3035 Photonics (3 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.

ENCE 3040 Semiconductor Microtechnology (3 qtr. hrs.)
An introductory course in the characterization and processing of semiconductors and other materials used in electronic devices. Topics include growth and preparation of semiconductors, type conversion with emphasis on diffusion, formulation of insulating layers, with emphasis on oxidation, photolithography, interconnections, formation of ohmic contacts, and bonding. Fabrication of microelectronic devices. Measurements may include determination of type, carrier concentration, carrier lifetime, and electrical characteristics. Common laboratory procedures in microelectronics.

ENCE 3050 Plasma Processing of Materials (3 qtr. hrs.)
Basic physics of the plasma state including electromagnetics and statistical mechanics, particle collision mechanisms, gas and surface chemistry, and interactions with macroscopic surfaces. Examination of materials processing issues primarily used in integrated circuit manufacturing, including etching, deposition, implantation and ashing. Diagnostics for both plasmas and materials processing.
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 (3 qtr. hrs.)
Introductory course on modern 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 non-coherent digital modulation techniques. Bandwidth efficiency and transmission of digital data through band-limited channels.

ENEE 3150 Communication Systems Lab (3 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 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 3630 Antennas (3 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.

ENEE 3640 Introduction to EMC (3 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 various passive networks; 2-, 3-, and 4-port passive 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.

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 Intro to Telecomm 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 DSP (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 4010 Quantum Optics & Electronics (4 qtr. hrs.)
Principles of quantum mechanics; lattice vibrations and motion of electrons in solids; scattering; mesoscopic systems; quantum theory of radiation.

ENEE 4020 Lasers & Nonlinear Optics (3 qtr. hrs.)
Optical resonators; media with gain and laser theory; laser operation and control; optical mixing; parametric amplification; detection.

ENEE 4080 Physical Optics (3 qtr. hrs.)
Interference and diffraction; interferometry; polarization; coherence; Fourier optics and image formation; holography.

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

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

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

ENEE 4410 Adv Signal Processing & Comm (4 qtr. hrs.)
Detection, estimation; optimal linear receivers; deterministic and random signals; spectral estimation; parametric modeling of signals; discrete and continuous filters.

ENEE 4415 Advanced DSP (3 qtr. hrs.)
Study of linear discrete-time systems used to perform operations on random processes for purposes of signal detection, estimation, enhancement and parametric modeling; linear difference equations, Z-transforms, random sequences, state variables, matched filtering Wiener filtering.

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 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 Adv Optical Fiber Comm (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 4671 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 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 & 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 (3 qtr. hrs.)
Adaptive control techniques; learning systems; and stochastic learning system theory are covered.

ENEE 4800 Adv 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 3610 Engineering Analysis (3 qtr. hrs.)
Applied mathematics for engineers. Generalized Fourier analysis, complex variables, vector calculus,
test to Bessel functions, and applied probability and statistics. Prerequisites: MATH 2070, MATH
2080.

ENGR 3630 Finite Element Methods (3 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 Robotics (3 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 & Power Sys (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. Prerequisite: varies with
offering.
ENGR 4620 Optimization In Design (3 qtr. hrs.)
Optimization, one-dimensional; search algorithms, design constraints, penalty functions, multidimensional optimization techniques, economics, interdisciplinary aspects of optimization.

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

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

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

Mechanical Engineering

ENME 3230 Intro to Nondestructive Eval (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.

ENME 3545 Mechanisms (3 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 Adv Mechanisms & 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 3730 Adv Engr 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 3851 Thermal Systems Design (3 qtr. hrs.)
Applications of fluid flow, thermodynamics and heat transfer principles to design of thermal systems; economics; curve fitting; system simulation; optimization techniques. Design problems specified by the instructor from the following topics: heat exchanger networks, energy conversion, power and refrigeration cycles and building heating or cooling.
ENME 3860 Intro 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 Adv Finite Element Analysis (3 qtr. hrs.)
The advanced use of finite element methods in two and three dimensions with applications to solids. Prerequisite(s): ENGR 3630 or equivalent.

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; 2D problems in elasticity; energy theorems; wave propagation; numerical techniques.

ENME 4370 Plasticity (3 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 4610 Inviscid Flow (3 qtr. hrs.)
Applicability of ideal flow theory, equations of motions, potential flow, circulation and vorticity, axially symmetric flow; review of complex variables and potential theory, conformal mappings, airfoil theory, stratified fluids, and gravity wave mechanics.

ENME 4630 Viscous Flow (3 qtr. hrs.)
Low Reynolds number flows, incompressible and compressible laminar boundary layer theory; similarity theory; separation, transition, and turbulent boundary layers.

ENME 4640 Compressible Flow (3 qtr. hrs.)
Energy, continuity, and momentum principles applied to compressible flow; one, two and three-dimensional subsonic, supersonic, and hypersonic flows; normal and oblique shocks; methods of characteristics.

ENME 4700 Conductive Heat Transfer (3 qtr. hrs.)
Analytical and numerical methods for the determination of the conduction of heat in solids.

ENME 4710 Convective Heat Transfer (3 qtr. hrs.)
Conservation equations for flow of real fluids; analysis of heat transfer in laminar and turbulent, incompressible and compressible flows; internal and external flows; free convection; variable wall temperature; effects of variable fluid properties; analogies among convective transfer processes.

ENME 4720 Radiative Heat Transfer (3 qtr. hrs.)
Radiant intensity and flux; radiation properties of walls, gases, and particulates; heat transfer by combined conduction, convection, and radiation in an absorbing and absorbing media; applications to industrial, aerospace, energy-conversion, and environmental problems.

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.)

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 3210 Mech Behavior of Materials (3 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 3430 Diffraction & 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 3440 Diffraction & Structure II (3 qtr. hrs.)
Application of diffraction methods to materials science and engineering. Calculation of diffracted intensities, temperature effects, order/disorder. X-ray optics, grazing incidence diffraction, reflectometry, applications to thin films. Precise lattice parameter measurement, peak broadening, x-ray stress determination. Laboratory experiments on selected topics.

MTSC 4130 Intro 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 4140 Surface Analysis (3 qtr. hrs.)
Methods for identifying elemental composition, chemical states, and bonding at surfaces and interfaces with the primary emphasis on SIMS; secondary neutral mass spectrometry (SNMS); ion scattering spectrometry (ISS); Rutherford backscattering spectrometry (RBS); Auger electron spectroscopy (AES); X-ray and UV photoelectron spectroscopies (XPS, UPS); core-level electron energy loss spectroscopy (EELS); the use of ions, electronics, and photons for surface analysis, either in the stimulation or detection mode; combined use of ion bombardment and surface analysis for obtaining the composition-in-depth of solids, emerging spectroscopies that probe chemical bonding at interfaces will also be discussed.

MTSC 4210 Composite Materials I (3 qtr. hrs.)
An introduction to composite materials: properties of fibers and matrices, fiber architecture, elastic deformation of laminae and laminates, interfaces in composites.

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.

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 4235 Polymer Science II (3 qtr. hrs.)
Properties of linear organic polymers; rubber elasticity; linear viscoelastic behavior; time-temperature superposition, dynamic mechanical behavior; large strain deformation behavior, dielectric behavior.

MTSC 4250 Struct & Props 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 4255 Struct & Props of Ceramics II (3 qtr. hrs.)
Thermal properties of ceramic materials (heat capacity, conductivity, expansion); mechanical properties (plastic deformation and creep, elasticity, strength and toughness, residual and thermal stresses); electrical and dielectric properties (ionic and electronic conduction, dielectric constants and loss factors, polarization; optical properties).
MTSC 4310 Design w/ Materials w/ Var Props (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.

Business

BUS 4100 Values-Based Leadership (4 qtr. hrs.)
Evaluate and apply legal, ethical, and public policy frameworks to stakeholder relationships and leadership challenges. Required for all graduate business students.

BUS 4200 The 21st Century Professional (4 qtr. hrs.)
Develop capacities and skills for effective communications and leadership, establish the foundation for lifelong personal and professional development. Prerequisite(s): BUS 4100. Required for all graduate business students.

BUS 4300 The Global Information Economy (4 qtr. hrs.)
Apply relevant and effective technology strategies to obtain competitive advantage in the dynamic global business environment. Prerequisite(s): BUS 4100 & 4200. Required for all graduate business students.

MGMT 4290 Business Strategy (4 qtr. hrs.)
Integrates technical knowledge and managerial skills with key business issues; in-depth cases, diverse topics such as financial planning, market segmentation, budgeting, strategy development, operations management, information systems; breadth of case studies address decision-making in small start-up firms to multi-national organizations; internal aspects of organization, external forces affecting organizational performance. Prerequisite(s): Completion of all business core requirements.

Chemistry

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.

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 3310 Molecular Structure and Energetics II (3 qtr. hrs.)
This is a course in computational methods in chemistry.

CHEM 3310 Molecular Structure and Energetics III (3 qtr. hrs.)
Topics include statistical mechanics of ideal gases, statistical approach to chemical reactions and a microscopic approach to rate processes.

Physics

PHYS 3111, 3112, 3113 Quantum Physics I, II, III (3 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)
Crystalline 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.), II (2 qtr. hrs.)
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 Adv 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 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.

FACULTY

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