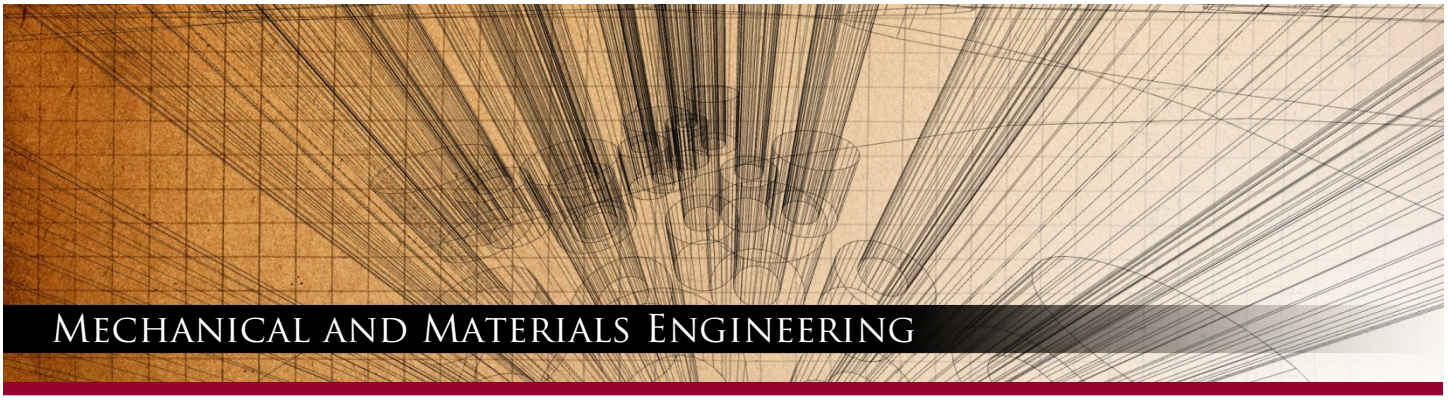

MECHANICAL AND MATERIALS ENGINEERING 2013–2014

Why study engineering at the University of Denver?

The University of Denver's department of mechanical and materials engineering (MME) is creating the future of technology by providing a graduate education emphasizing cross- disciplinary knowledge. A distinguished faculty is creating multidisciplinary education and research programs that anticipate technological trends in research and industry. Engineering graduate students join the faculty in conducting cutting-edge research in emerging disciplines to develop unique solutions to old and new problems and opportunities.

The well-equipped laboratories in the department contain state-of-the-art equipment and software to support research in biomedical engineering, advanced materials, atmospheric aerosol science, and mechanical design among others. Small classes support our multidisciplinary and real-time focus by providing close contact between students and faculty, which allows us to meet students' individual career goals.

In addition, recognizing the different aims and goals of students, we offer joint degree programs in management and engineering for students who wish to add to their technical skills and acquire business skills; computer science and engineering for those who desire expertise in both areas; nanoscale science and engineering for those who desire practical training in this rapidly growing field; and in materials science for those needing in-depth expertise on modern and advanced materials.

Denver is a first-rate location for business, governmental and laboratory partnerships, and technology employment. The Colorado Front Range is consistently rated as one of the top high- tech areas in the country, and the University of Denver is located just minutes from the Denver Technological Center, site of many top technology companies. The department of mechanical and materials engineering is committed to active collaboration with these industry leaders. As a result, our students graduate with relevant research experience and a network of employment contacts in the technology sector.

UNIVERSITY of DENVER

Mechanical and Materials Engineering
Daniel Felix Ritchie School of Engineering and Computer Science
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Clarence M. Knudson Hall, Room 200
Denver, CO 80208
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http://mme.du.edu

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DEGREE REQUIREMENTS

Time Commitment

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 normal business hours. Many employers will permit additional flexibility by releasing employees early to attend classes.

International Students: International Students pursuing either MS or PhD must be registered as full-time while pursuing their degree. This requires taking two courses or the equivalent in independent study/research (eight quarter hours) per quarter for fall, winter and spring.

Master of Science: 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.

Doctor of Philosophy: With a MS the PhD degree programs can generally be completed in about four to six years depending on the research topic. All requirements for the degree must be completed within seven or eight years from admission to candidacy. For part-time students who are working in industry positions a topic related to the job function may be acceptable as the dissertation research topic. Furthermore, students may request for a qualified staff member at the place of employment to serve as a special committee member on the dissertation 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 a PhD degree.

Master of Science General Degree Requirements

MS Minimum Credit Requirements

Every candidate for the MS degree must complete 45 quarter hours of credit, at least 36 of which must be completed at the University of Denver. An overall GPA of 3.0 is required for the degree and any individual grade lower than C- renders the credit unacceptable.

MS Program Structure

Candidates for the degree of Master of Science 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 GRAs are required to elect the thesis option. These programs are designed to be completed in about six quarters if two courses (eight quarter hours) are taken each quarter.

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Master of Science in Mechanical Engineering

The Master of Science in Mechanical Engineering (MS ENME) 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; 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 mechanical engineering and related fields. Each program prepares the student for academic and industrial advancement. All programs offer a thesis and a non-thesis option.

Admission to the MS ENME Program

A Bachelor of Science degree in Mechanical Engineering (BS ENME) or closely related field is required for admission to the MS ENME 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.

MS ENME **Minimum** Quarter Hour Requirements		
	Thesis	Non-Thesis
Core	9	9
Technical Electives	15	25
Advanced Math	3	6
Thesis	13	NA
Total	**45 qh**	**45 qh**

Course Requirements

Three courses from the core course list and 1 (thesis) or 2 (non-thesis) courses from the advanced math list are required. Note that one of the three math courses marked with an asterisk (*) is required to be taken in the first year. A minimum of six 4000-level courses of at least 3 QH each are required for non-thesis track; four 4000-level courses of at least 3 QH each are required for thesis track. No courses at the 1000 or 2000 level are acceptable.

Core Courses

ENBI 4800 Advanced FEA
ENGR 3630 Finite Element Methods
ENME 3545 Mechanisms
ENME 3555 Advanced Dynamics
ENME 3651 Computational Fluid Dynamics
ENME 4670 Advanced CFD
ENME 4800 Advanced Fluids
ENME 4800 Viscous Flow

Advanced Math Courses

ENGR 3610 Engineering Analysis
ENGR 3620 Advanced Engineering Mathematics
ENGR 4350 Reliability*
ENGR 4620 Optimization*
ENGR 4810 Numerical Methods*

The MS ENME program offers three areas of specialization:

Structure and Behavior of Materials: This area of concentration prepares students for research and development work in areas of technology that 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, and polymers) and characterization techniques (acoustic emission, X-ray diffraction and instrumentation).

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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 students with a thorough foundation in the principles of thermodynamics, fluid mechanics, or heat and 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 to master a particular system, process or engine.

Mechanical Design and Analysis: 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.

Master of Science in Bioengineering

The Master of Science in Bioengineering (MS ENBI) integrates engineering sciences with biomedical sciences and clinical practice to provide the skill set needed by bioscience companies. The Department of Mechanical and Materials Engineering—in collaboration with the Departments of Electrical and Computer Engineering, Chemistry & Biochemistry, Biological Sciences, and Physics & Astronomy—has designed a cross-disciplinary master of science program to address industrial requirements and the desired qualifications of a 21st century workforce in bioengineering businesses. Students with bachelor's degrees in chemistry, biological sciences or physics, as well as those with accredited engineering degrees, acquire a specialized expertise in bioengineering by designing programs which leverage the individual students' undergraduate experience and expertise resident at DU. This program offers both thesis and non-thesis options.

Admission to the MS ENBI Program

A Bachelor of Science in engineering, chemistry, biology or physics is normally required for admission to the MS ENBI program. A background including undergraduate research in an area related to bioengineering is also very helpful. Students may be required to complete prerequisite undergraduate courses.

MS ENBI **Minimum** Quarter Hour Requirements		
	Thesis	Non-Thesis
Core	6	6
Minor Electives	8	8
Technical Electives	9	17
Advanced Math	3	3
Thesis	13	NA
Total	**45 qh**	**45 qh**

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Course Requirements

Two courses from the core course list and 1 course from the advanced math list are required. Note that the math course is required to be taken in the first year. In addition, the tool test is required for candidates with non-engineering undergraduate degrees. The course work for both the thesis and non-thesis options in bioengineering must be comprised of a minimum of four 4000-level courses. No courses at the 1000 or 2000 level are acceptable.

Core Courses

ENBI 4500 Pharmaceutical Biofluids
ENBI 4510 Biomechanics
ENBI 4800 Cardiovascular Engineering
ENBI 4800 Computational Biomechanics
ENBI 4800 Physiological Biofluids

Advanced Math Courses

ENGR 4350 Reliability
ENGR 4620 Optimization
ENGR 4810 Numerical Methods

Minor Elective Courses

A minor is required by each student and is intended to provide bioengineering students with additional knowledge in an area unassociated with their undergraduate degree. Candidates with non-engineering undergraduate degrees must take courses in engineering which provide critical foundational knowledge. Candidates with engineering undergraduate degrees must take course work in biological sciences or chemistry and biochemistry.

Technical Elective Courses

Technical elective courses are intended to provide bioengineering students an opportunity to take additional coursework that will expand their knowledge of advanced engineering topics. The courses must be chosen primarily from engineering course offerings numbered 3000 or higher and approved by the student's advisor.

Tool Requirement

As employers of graduates of this degree will inherently expect a basic competency in foundational engineering skills, students must demonstrate these before advancing to candidacy. Candidates with BS degrees from accredited engineering schools will be exempt from the tool requirement because their degree is sufficient proof of foundational engineering skills. Candidates with undergraduate degrees from non-engineering majors will be required to pass a tool requirement.

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Master of Science in Engineering

The Master of Science in Engineering (MS ENGE) is designed to advance the knowledge of students in areas differing from those in which they received their bachelor's degree. The program is particularly intended for students with bachelor's degrees in the natural sciences, mathematics, computer science or engineering who are making a change of discipline or wanting to develop expertise in an engineering area, often one that is of emerging importance or interdisciplinary in nature. The program combines a solid background in an area of engineering with a distinctly personal specialization. It enables the student to focus on a particular area of engineering, while providing breadth through its flexible minor or technical elective requirement addressing the student's specific interests.

A concentration in engineering management is also offered (see below). The courses in the Engineering Management Concentration are focused on developing core knowledge and competencies in innovation and entrepreneurship, and providing concrete tools to successfully translate ideas and initiative into marketplace success.

Admission to the MS ENGE Program

A Bachelor of Science degree in engineering, biology, chemistry, physics, mathematics, or computer science is required for admission to the MS ENGE program. Students may also be required to complete prerequisite undergraduate courses. A declared interest is an essential part of the graduate application. This program offers thesis and non-thesis options.

MS ENGE **Minimum** Quarter Hour Requirements			
	Thesis	Non-Thesis	CM
Core	9	9	9
Engineering Electives	15	25	12
Management Electives	NA	NA	16
Advanced Math	3	6	3
Thesis	13	NA	NA
Total	**45 qh**	**45 qh**	**45 qh**

Engineering (Non-Management) Course Requirements

Three courses from the Bioengineering, Mechanical Engineering, Materials Science, Electrical Engineering, or Computer Engineering core course lists (no more than 2 from any single discipline) and 1 (thesis) or 2 (non-thesis) courses from the advanced math list are required. Note that one of the three math courses marked with an asterisk (*) is required to be taken in the first year. A minimum of six 4000-level courses of at least 3 QH each are required for non-thesis track; four 4000-level courses of at least 3 QH each are required for thesis track. No courses at the 1000 or 2000 level are acceptable.

Advanced Math Courses

ENGR 3610 Engineering Analysis
ENGR 3620 Advanced Engineering Mathematics
ENGR 4350 Reliability*
ENGR 4620 Optimization*
ENGR 4810 Numerical Methods*

Program Requirements for the MS ENGE (CM):

Concentration in Engineering Management

The degree of Master of Science in Engineering allows students to pursue a concentration in engineering management. This is an engineering degree with both engineering and management focuses. The Concentration in Engineering Management is designed to meet the increasing needs of students to enhance their career opportunities as managers or as entrepreneurs by supplementing advanced engineering knowledge with a fundamental understanding of business principles within the context of technology enterprises. Drawing upon the strengths of both SECS and the Daniels College of Business, the program provides the relevant content for graduates to lead technology enterprises.

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Engineering with Management Core Requirements

Two courses from the Bioengineering, Mechanical Engineering, Materials Science, Electrical Engineering, or Computer Engineering core course lists and 1 course from the advanced math list are required. Note that the math course is required to be taken in the first year. A minimum of six 4000-level courses of at least 3 QH each are required for non-thesis track; four 4000-level courses of at least 3 QH each are required for thesis track. No courses at the 1000 or 2000 level are acceptable.

Engineering with Management Core Courses

ENGR 4810 Project Management
ENGR 4810 Operations Management
MGMT 4630 Strategic Human Resource Management
MGMT 4690 Strategic Management
MGMT 4290 Business Strategy
MGMT 4490 Global Strategy
MKTG 4610 Marketing Strategy
IMBA 4142 Global Management
BUS 4630 Creating Sustainable Enterprises

Advanced Math Courses

ENGR 4350 Reliability
ENGR 4620 Optimization
ENGR 4810 Numerical Methods

Master of Science in Materials Science

The Master of Science in Materials Science (MS MTSC) program 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 MME as the administering department. The programs reflect the 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.

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 that stresses fundamentals. This program offers thesis and non-thesis options.

Admission to the Programs

A bachelor's degree in materials science or closely related field (physics, metallurgy, engineering, chemistry is usually required for admission. A Master's degree in materials science or closely related field can also enroll in the materials science PhD program. If the student did not receive adequate preparation for studying materials, they may need to take several prerequisite courses in materials science.

MS MTSC **Minimum** Quarter Hour Requirements		
	Thesis	Non-Thesis
Core	9	9
Technical Electives	15	25
Advanced Math	3	6
Thesis	13	NA
Total	45 qh	45 qh

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Course Requirements

Three courses from the core course list and 1 (thesis) or 2 (non-thesis) courses from the advanced math list are required. Note that one of the three math courses marked with an asterisk (*) is required to be taken in the first year. A minimum of six 4000-level courses of at least 3 QH each are required for non-thesis track; four 4000-level courses of at least 3 QH each are required for thesis track. No courses at the 1000 or 2000 level are acceptable.

Core Courses

MTSC 4010 Mechanical Behavior of Materials
MTSC 4020 Composite Materials I
MTSC 4215 Composite Materials II
MTSC 4450 Fracture Mechanics
ENME 4400 Fatigue
ENME 4800 Advanced Mechanics of Materials

Advanced Math Courses

ENGR 3610 Engineering Analysis
ENGR 3620 Advanced Engineering Mathematics
ENGR 4350 Reliability*
ENGR 4620 Optimization*
ENGR 4810 Numerical Methods*

Master of Science in Nanoscale Science and Engineering

This program shares faculty and other resources with existing graduate programs in NSM and SECS. In order to make it easier for students to migrate between different programs, the program is structured similarly to other existing graduate programs in NSM and SECS. All NSM and SECS graduate programs focus on the research component. Therefore, course work credit is supplemented by the significant amount of credit earned from independent study/independent research courses taken in order to satisfy minimum credit requirements to earn a degree.

A satisfactory quality of achievement with a grade point average of 3.0 or better is required in graduate course work accepted for the degree. The average is determined on the basis of the university's grading system. In no case may more than one-fourth of the hours accepted toward the degree be of C grade. A grade lower than C- renders the credit unacceptable for meeting degree requirements.

The structure of the program is as follows:

- Core courses
- Elective courses
- Examinations

Admission to the Program

The interdisciplinary nature of this graduate program mandates certain flexibility in order to accommodate students with a variety of backgrounds. The program accepts students with a Bachelor of Science, Bachelor of Arts, Master of Science, or Master of Arts in biological sciences, chemistry, biochemistry, computer science, engineering, physics or related discipline. As a minimum, to be admitted into the program, students are expected to have earned as a part of their undergraduate degree:

- 1 year of calculus
- 1 year of algebra- or calculus-based physics with accompanying laboratory
- 1 quarter of general chemistry with accompanying laboratory

Furthermore, the program accepts students with a Master of Science or Master of Arts degrees in biological sciences, biophysics, chemistry, biochemistry, computer science, engineering, physics or related discipline.

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Thesis Option

A thesis permits exceptional candidates an opportunity to gain depth in a chosen area of study. Thesis candidates work closely with a thesis adviser, and thus this option requires support from a qualified faculty member. The thesis option is required for all graduate research assistants and graduate teaching assistants. A grade of C or better must be obtained in each course for that course to count toward the 45-quarter-hour requirement. The course work for the specialty track and technical electives must consist of a minimum of 12 quarter hours of 4000-level courses. To satisfy graduation requirements, candidates must maintain a course GPA of 3.0 (excluding thesis credits).

All students pursuing M.S. with thesis defend their thesis before the candidate's masters committee, as specified in the University of Denver's Graduate Policy Manual.

Course Requirements

The course work for the core courses and technical electives must consist of a minimum of 12 quarter hours of 4000-level courses:

The thesis research is normally carried out through independent study (IS) and independent research (IR) credits. The maximum number of IS/IR quarter hours in thesis research that can be applied toward the total quarter hour requirement is 15. M.S. students not pursuing a Thesis option are required to take five quarter hours of independent study on a selected topic.

Non-thesis Option

The more flexible of the two options, this is designed with the working professional in mind. A grade of C or better must be obtained in each course for that course to count toward the 45-quarter-hour requirement. To satisfy graduation requirements, candidates must maintain a course GPA of 3.0. The course work for the specialty track and technical elective areas must consist of a minimum of 24 quarter hours of 4000-level courses.

Course Requirements

The course work for the core courses and technical electives must consist of a minimum of 24 quarter hours of 4000-level courses.

M.S. students not pursuing a thesis option are required to take five quarter hours of independent study on a selected topic.

Core Courses

Core curriculum is based on courses regularly offered by the six constituent departments (biological sciences, chemistry and biochemistry, computer science, electrical and computer engineering, mechanical and materials engineering, and physics and astronomy). The core courses are as follows (up to 30 QH).

CHEM	3320	Structure and Energetics II
BIOL	3705	Advanced Topics in Molecular Biology
COMP	3354	Introduction to Systems Programming **or**
COMP	3371	Advanced Data Structures and Algorithms
ENGR	4200	Introduction to Nanotechnology
ENGR	4210	Intro to Nano-Electro-Mechanical Systems **or** ENGR 4220 Intro to Micro-Electro-Mechanical Systems
ENME	4310	Computational Methods for Mechanics and Materials
PHYS	3111	Quantum Physics I
PHYS	4411	Advanced Condensed Matter Physics I

Core curriculum assures that all students have knowledge of a certain number of topics. Therefore, core courses taken are dependent on the background of a particular student and are determined by a graduate program adviser upon the student's admission based on the degree earned and courses taken, as evidenced by the available transcripts from each institution attended. A maximum of four core courses from this list can be waived. ENGR 4200 (Introduction to Nanotechnology) is required for all students.

Elective Courses

Elective courses are designed to give students a more specialized knowledge and prepare them for thesis/dissertation research if pursued. M.S. students have to take at least one elective course from this list, excluding independent study and independent research courses. The following regularly offered courses are currently included:

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BIOL 3642 Neuropharmacology
CHEM 3110/CHEM 3120/CHEM 3130
Chemical Systems I/II/III
CHEM 3220 Advanced Analytical Chemistry
COMP 3351 Programming Languages
COMP 3709 Computer Security
COMP 3381 Software Engineering I
COMP 3421 Database Organization and Management I
COMP 4704 Bioinformatics
ENEE 3011 Physical Electronics
ENEE 4035 Nanophotonics
ENGR 3100 Instrumentation and Data Acquisition
ENGR 4350 Reliability
ENME 4660 Microheat Exchanger
PHYS 3112 Quantum Physics II
PHYS 3841 Thermal Physics I
PHYS 4111/PHYS 4112
Quantum Mechanics I/II
PHYS 4412 Advanced Condensed Matter Physics II
PHYS 4611/PHYS 4612
Advanced Electricity and Magnetism I/II
PHYS 4811 Statistical Mechanics I

The intent is to amend this list with additional existing and new courses from NSM, SECS, as well as Daniels College of Business and Sturm College of Law courses.

The credit earned through other graduate courses at the 3000 and higher level not listed above can be applied toward the total quarter hour requirement with the approval of the graduate program adviser.

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DOCTOR OF PHILOSOPHY

General Program Requirements

PhD Students with a Bachelor of Science:

For students entering with a bachelor's degree:

90 quarter hours are required, 72 of which must be completed at the University of Denver.

A minimum of 48 quarter hours must be at the 4000 or 5000 level and may include as many dissertation research hours (Independent Research and Independent Study) as considered appropriate by the advisor. No courses at the 1000 or 2000 level are acceptable.

An overall GPA of 3.0 is required for the degree and any individual grade lower than a C- renders the credit unacceptable.

The area of specialization will consist of 15 quarter hours of course work (with a minimum of three 4000-level courses, excluding independent research).

An additional 12 quarter hours of course work (excluding independent research) are required as related technical electives.

A three-quarter hour advanced mathematics requirement must also be satisfied.

Prior to completion of the comprehensive exam, the plan of study must be approved by the student's PhD committee.

General Engineering, Interdisciplinary Engineering and Mechanical Engineering

For those coming in with a bachelor's degree, the technical electives must be in engineering (e.g. bioengineering, mechatronic systems, environmental systems, or nanotechnology) or related areas (e.g., mathematics, computer science, physics, chemistry or cognitive sciences).

PhD Students with a Master of Science:

- If a student is admitted with a closely related master's degree, up to 45 hours may be transferred and applied to the doctorate degree.
- A minimum of 45 quarter hours is required at the University of Denver.
- An overall GPA of 3.0 is required for the degree and any individual grade lower than a C- renders the credit unacceptable.
- The student with his or her advisor will develop an appropriate program consisting of a minimum of 36 quarter hours at the 4000 or 5000 level, which may include as many dissertation research hours (Independent Research and Independent Study) as considered appropriate by the advisor. No courses at the 1000 or 2000 level are acceptable. (Check the Nanoscale Science and Engineering program for their requirements.)
- The student with his or her advisor will develop an appropriate plan of study with an area of specialization, technical electives and advanced mathematics.
- Prior to completion of the comprehensive exam, the student's plan of study must be approved by the student's PhD committee.

PhD 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. For those applicants from industry with established special degree programs with SECS, the residency requirement can be waived by the dean of SECS. The Nanoscale Science and Engineering PhD program does not have this requirement.

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PhD Qualifying Examination

First and foremost, each student admitted to the PhD program must pass the qualifying exam to obtain candidacy or official entrance into the doctoral program—normally within the first two academic years of study. Students must pass the qualifying exam (minimum of 70 percent) in order to be advanced to preliminary candidacy. This exam may be retaken once.

- General Engineering, Interdisciplinary Engineering and Mechanical Engineering: Students must take three exams. The Design exam is required for all candidates. The other two exams should be related to the student's research area and be selected with the consent of PhD advisor(s) and the committee.
- Materials Science and Nanoscale Science and Engineering: Students must take five exams related to the student's research area.

PhD Comprehensive Examination

Generally within three years of attaining preliminary candidacy, but at least one year before the anticipated date of graduation, the student should schedule and take the comprehensive examination after substantial progress in the research is achieved. This is an oral examination attended by their dissertation committee. Upon a successful oral presentation, student is advanced to final PhD candidacy.

PhD Dissertation

The student is required to complete and defend a dissertation of publishable quality based on the student's original research. A summary of the dissertation must be presented in a public seminar and subsequently defended by the student in the final oral examination.

Doctor of Philosophy in Engineering

The objective of the Doctor of Philosophy in Engineering (PhD ENGE) program is to provide an educational environment that encourages students to develop the ability to contribute to the advancement of science, engineering and technology through independent research. The PhD students of the 21st century may pursue academic, research, entrepreneurial and/or industrial careers. The MME department offers opportunities to develop individualized plans of study based on students' previous experience and desired research areas. The plan of study allows students to work on interdisciplinary research, while also satisfying the PhD in engineering degree requirements. The MME department offers two types of general PhD degrees:

- Engineering discipline: mechanical engineering, materials science and nanotechnology.
- Interdisciplinary: Combines an engineering discipline with a complementary discipline (e.g. business, natural sciences).

Admission to the Program

Students with a master's degree in computer, electrical, mechanical engineering or closely related areas may apply for the PhD program 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 (computer, electrical or mechanical) programs.

Program Structure

Research requires an in-depth study of an engineering problem with a broad knowledge base in science and engineering. Therefore advanced courses are offered to strengthen the fundamentals and to broaden the engineering and science perspective.

Students entering the PhD ENGE program may take courses with a concentration in engineering management, or may undertake an interdisciplinary degree.

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The interdisciplinary PhD program offers opportunities for students to develop a plan of study combining engineering and a complementary discipline. In the plan of study, coursework in the complementary discipline can be included up to the maximum number of technical elective quarter hours. The student's plan of study must be approved by his/her PhD committee and the department chair. When the student is completing research and course work in a complementary discipline, the student's PhD committee must include a faculty member from the related department or division/school.

Doctor of Philosophy in Materials Science

The Doctor of Philosophy in Materials Science (PhD MTSC) is designed to prepare the student for research or faculty position in the materials field. The program is multidisciplinary and involves the departments of Physics and Astronomy, Chemistry and Biochemistry, Electrical and Computer Engineering, and MME, with MME as the administering department. The programs reflect the 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.

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 that stresses fundamentals.

Admission to the Program

A bachelor's degree or master's degree in materials science or closely related field (physics, metallurgy, engineering or chemistry) is usually required for admission. If the student did not receive adequate preparation for studying materials, they are encouraged to apply for the master's degree.

Doctor of Philosophy in Mechanical Engineering

The objective of the Doctor of Philosophy in Mechanical Engineering (PhD ENME) program is to provide an educational environment that encourages students to develop the ability to contribute to the advancement of mechanical engineering through independent research.

Admission to the Program

Students with a master's degree in mechanical engineering or closely related areas may apply for the PhD program in mechanical 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 ENME program.

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Doctor of Philosophy in Nanoscale Science and Engineering

This program shares faculty and other resources with existing graduate programs in NSM and SECS. In order to make it easier for students to migrate between different programs, the program is structured similarly to other existing graduate programs in NSM and SECS. All NSM and SECS graduate programs focus on the research component. Therefore, coursework credit is supplemented by the significant amount of credit earned from independent study/independent research courses taken in order to satisfy minimum credit requirements to earn a degree.

A satisfactory quality of achievement with a grade point average of 3.0 or better is required in graduate course work accepted for the degree. The average is determined on the basis of the university's grading system. In no case may more than one-fourth of the hours accepted toward the degree be of C grade. A grade lower than C- renders the credit unacceptable for meeting degree requirements.

The structure of the program is as follows:

- Core courses
- Elective courses
- Examinations

Admission to the Program

The program accepts students with a master of science or Master of Arts degrees in biological sciences, biophysics, chemistry, biochemistry, computer science, engineering, physics or related discipline. A maximum of 45 quarter hours of credits could be transferred toward the total quarter-hour requirement.

Students with a Bachelor of Science

The student, along with his or her adviser, will develop an appropriate plan of study with an area of specialization, technical electives and advanced mathematics. The area of specialization will consist of 15 quarter hours of course work (with a minimum of nine quarter hours of 4000-level courses, excluding independent research). An additional 12 quarter hours of course work (excluding independent research) are required as related technical electives.

Furthermore, a three-quarter hour advanced mathematics requirement must also be satisfied. Advanced mathematics courses at the 3000 level or higher are selected with the prior approval of the student's adviser. Prior to completion of the comprehensive exam, the plan of study must be approved by the student's Ph.D. committee.

Students with a Master of Science

The student, along with his or her adviser, will also develop an appropriate plan of study with an area of specialization, technical electives and advanced mathematics. Prior to completion of the comprehensive exam, the student's plan of study must be approved by the student's Ph.D. committee.

Core Courses

Core curriculum is based on courses regularly offered by the six constituent departments (biological sciences, chemistry and biochemistry, computer science, electrical and computer engineering, mechanical and materials engineering, and physics and astronomy). The core courses are as follows:

CHEM	3320	Structure and Energetics II
BIOL	3705	Advanced Topics in Molecular Biology
COMP	3354	Introduction to Systems Programming or
COMP	3371	Advanced Data Structures and Algorithms
ENGR	4200	Introduction to Nanotechnology
ENGR	4210	Intro to Nano-Electro-Mechanical Systems
	or	
ENGR	4220	Intro to Micro-Electro-Mechanical Systems
ENME	4310	Computational Methods for Mechanics and Materials
PHYS	3111	Quantum Physics I
PHYS	4411	Advanced Condensed Matter Physics I

Core curriculum assures that all students have knowledge of a certain number of topics. Therefore, core courses taken are dependent on the background of a particular student and are determined by a graduate program adviser upon student's admission based on the degree earned and courses taken, as evidenced by the available transcripts from each institution attended. A maximum of two core courses from this list can be waived. ENGR 4200 (Introduction to Nanotechnology) is required for all students.

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Elective Courses

Elective courses are designed to give students a more specialized knowledge and prepare them for dissertation research. Students have to take at least four elective courses from this list, excluding independent study and independent research courses. The following regularly offered courses are currently included:

BIOL 3642 Neuropharmacology
CHEM 3110/CHEM 3120/CHEM 3130
Chemical Systems I/II/III
CHEM 3220 Advanced Analytical Chemistry
COMP 3351 Programming Languages
COMP 3709 Computer Security
COMP 3381 Software Engineering I
COMP 3421 Database Organization and Management I
COMP 4704 Bioinformatics
ENEE 3011 Physical Electronics
ENEE 4035 Nanophotonics
ENGR 3100 Instrumentation and Data Acquisition
ENGR 4350 Reliability
ENME 4660 Microheat Exchanger
PHYS 3112 Quantum Physics II
PHYS 3841 Thermal Physics I
PHYS 4111/PHYS 4112
Quantum Mechanics I/II
PHYS 4412 Advanced Condensed Matter Physics II
PHYS 4611/PHYS 4612
Advanced Electricity and Magnetism I/II
PHYS 4811 Statistical Mechanics I

The intent is to amend this list with additional existing and new courses from NSM, SECS, as well as Daniels College of Business and Sturm College of Law courses.

The dissertation research is normally carried out through independent study and independent research credits. The maximum number of IS/IR quarter hours in dissertation research that can be applied toward the total quarter hour requirement is 15.

The credit earned through other graduate courses at the 3000 and higher level not listed above can be applied toward the total quarter hour requirement with the approval of the graduate program adviser.

Ph.D. Examination Structure

After successfully passing core courses, all students intending to pursue a Ph.D. degree, must take a written comprehensive examination. This examination is based on the core courses and is administered by the graduate program committee. The comprehensive examination can have two possible outcomes:

(1) Fail: Student will be moved to the M.S. level
(2) Pass at the Ph.D. level: advancement to preliminary Ph.D. candidacy

The comprehensive examination can be retaken once for students failing on the first attempt.

Students advanced to the Ph.D. preliminary candidacy are required to give an oral presentation on their dissertation research before their dissertation committee after substantial progress in the research is achieved, but at least one year before the anticipated date of graduation. Upon a successful oral presentation, student is advanced to final Ph.D. candidacy.

All students pursuing a Ph.D. degree defend their dissertation before the candidate's dissertation committee, as specified in the University of Denver's Graduate Policy Manual.

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MME lab manager/instructor

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Chair
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Maciej S. Kumosa, PhD
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Breigh Roszelle, PhD
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Richard M. Voyles*, PhD
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Carnegie Mellon University

James C. Wilson, PhD
Professor, Mechanical Engineering
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* Joint appointment in the MME department

OTHER FACULTY

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University of Arizona
(NANO Program)

Barry Zink, PhD
Associate Professor, Physics and Astronomy
University of California, San Diego
(NANO Program)

COURSE DESCRIPTIONS

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Bioengineering

ENBI 4500 Biofluids (4 qtr. hrs.)
The application of fluid dynamics theory and design to problems within the biomedical community. Specific topics covered 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 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.

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

ENBI 4991 Independent Study (1 to 5 qtr. hrs.)

ENBI 4992 Directed Study (1 to 5 qtr. hrs.)

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

General Engineering

ENGR 4200 Introduction to Nanotechnology (4 qtr. hrs.)
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, nanoparticle 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 issues of modeling of nanomaterials and nanostructures is also covered. Multi-scale 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 area of expertise.

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. Prerequisite: ENGR 3610 or equivalent.

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

COURSE DESCRIPTIONS (CONTINUED)

ENGR 4810 Advanced Topics (ENGR) (1 to 5 qtr. hrs.)

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

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

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

ENGR 5991 Independent Study (1 to 10 qtr. hrs.)

ENGR 5995 Independent Research (1 to 18 qtr. hrs.)

Mechanical Engineering

ENME 4020 Adv Finite Element Analysis (4 qtr. hrs.)

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 Adv. 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 4991 Independent Study (1 to 10 qtr. hrs.)

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. Prerequisites: ENME 2520, ENME 2541.

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 discretions 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. Prerequisite: ENME 2671 or instructor approval.

ENME 4310 Computational Methods for Mechanics and Materials (4 qtr. hrs.)
An introductory course for the general-purpose computational methods in advanced multi-scale materials and mechanics. Students learn the fundamentals 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 4660 Micro Heat Exchangers (4 qtr. hrs.)
Explores the advance principles and applications of fluid dynamics and heat transfer through the application to micro fluidic heat exchanger design and optimization. Students utilize Mathcad extensively to seek optimized exchanger performance within a clearly defined design space. Students also build small scale heat exchangers from their optimized designs. Prerequisite: ENME 2671.

ENME 4670 Advanced Computational Fluid Dynamics (4 qtr. hrs.)
Building 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 are discussed at length. Additionally, students learn how to set up automated design optimization using the latest software packages. Time permitting, students also are introduced to fluid-solid interaction modeling. Prerequisite: ENME 3651.

COURSE DESCRIPTIONS (CONTINUED)

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

ENME 4992 Directed Study (1 to 10 qtr. hrs.)

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

ENME 5991 Independent Study (1 to 10 qtr. hrs.)

ENME 5995 Independent Research
(1 to 10 qtr. hrs.)

Materials Science

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 4010 Mechanical Behavior of Materials
(4 qtr. hrs.)
Effects of microstructure on mechanical behavior of material; 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 properties of laminae and laminates, interface 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. Prerequisite: MTSC 4210

MTSC 4800 Advanced Topics (MTSC)
(1 to 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. hrs.)
Weekly presentations by graduate students, faculty, outside speakers, etc., on research in progress or other topics of interest.

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

MTSC 4992 Directed Study (1 to 10 qtr. hrs.)

MTSC 4995 Independent Research
(1 to 18 qtr. hrs.)

MTSC 5995 Independent Research
(1 to 18 qtr. hrs.)

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For More Information

A complete description of the program's official offerings and requirements is available from the department at http://mme.du.edu.