

# MECHANICAL AND MATERIALS ENGINEERING

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## Master's and Doctoral Degrees Offered

### 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.

Recognizing the different aims and goals of students, we offer several degree programs for students who wish to add to their technical skills in various areas: MS in Bioengineering; MS and PhD in Materials Science; and MS and PhD in Mechanical Engineering.

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.

### 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.

The master's program offer thesis and non-thesis options and can be completed in one (non-thesis track only) to four years depending on the number of courses taken per quarter. The choice of thesis or non-thesis can be made at any time, although a delay in declaration may impact the completion date.

The doctoral program is generally completed in three to seven years, depending on the number of courses taken per quarter and whether the student enters with a BS or MS.

A student not interested in pursuing a degree, but interested in taking an occasional course, may register as special status students (<http://www.du.edu/learn/graduates/degreeprograms>) by following an abbreviated admissions process. If at a later time the student chooses to enter a graduate degree program at DU, you may apply up to 15 special status credits to your degree, with departmental approval. Just follow the regular graduate application requirements, including submitting the application fee, to get started.

## Degree Programs

Below are our graduate engineering degrees:

- Master of Science in Bioengineering (MS ENBI)
- Master of Science in Engineering (MS ENGE) (<http://bulletin.du.edu/graduate/schoolscollegesanddivisions/danielfelixritchieschoolofengineeringandcomputerscience/engineering/#programofstudytext>)(See Department of Engineering program listing)
- Master of Science in Engineering with a Concentration in Management (MS ENGE (CM)) (<http://bulletin.du.edu/graduate/schoolscollegesanddivisions/danielfelixritchieschoolofengineeringandcomputerscience/engineering/#programofstudytext>)(See Department of Engineering program listing)
- Master of Science in Materials Science (MS MTSC)
- Master of Science in Mechanical Engineering (MS ENME)
- Doctor of Philosophy in Engineering (PhD ENGE) (<http://bulletin.du.edu/graduate/schoolscollegesanddivisions/danielfelixritchieschoolofengineeringandcomputerscience/engineering/#programofstudytext>)(See Department of Engineering program listing)
- Doctor of Philosophy in Materials Science (PhD MTSC)
- Doctor of Philosophy in Mechanical Engineering (PhD ENME)

## 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 Mechanical and Materials Engineering (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.

## 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.

## 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.

## 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 the Mechanical and Materials Engineering Department administering the degree. 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.

## 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 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.

## Doctor of Philosophy in Mechanical Engineering OR Materials Science

### Application Deadlines

- Fall 2018 Priority Deadline: November 3, 2017
- Fall 2018 Final Submission Deadline: June 1, 2018
- Winter 2019 Priority Deadline: June 1, 2018
- Winter 2019 Final Submission Deadline: November 3, 2018
- Spring 2019 Priority Deadline: August 1, 2018
- Spring 2019 Final Submission Deadline: January 7, 2019
- Summer 2019 Priority Deadline: October 1, 2018
- Summer 2019 Final Submission Deadline: April 1, 2019

### Admission Requirements

- **Online admission application**
- **\$65.00 Application Fee**
- **University Minimum Degree and GPA Requirements**
- **Transcripts:** (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/admission-process-and-standards-for-all-applicants/transcripts-and-proof-of-degree>) One official transcript from each post-secondary institution.

- **GRE** (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/admission-process-and-standards-for-all-applicants/university-admission-criteria>): The Graduate Record Examination (GRE) is required. Scores must be received directly from the appropriate testing agency by the deadline. The institution code for the University of Denver is 4842.
- **Letters of Recommendation**: Two (2) letters of recommendation are required. Letters should be submitted by recommenders through the online application.
- **Personal Statement**: A personal statement of at least 300 words is required. Your statement should include information concerning your life, education, experiences, interests and reason for applying to DU.
- **Résumé**: The résumé (or C.V.) should include work experience, research, and/or volunteer work.
- **Prerequisites**: Students with a master's degree in Mechanical Engineering or closely related areas may apply for the PhD program in Mechanical Engineering (ENME). Admission with only a Bachelor of Science degree in this field is also possible, but such students are encouraged to enroll first in the MS ENME program.
- **Other Requirements**: We recommend PhD applicants contact faculty to find a research advisor BEFORE submitting the application. If we receive an application and there is no research advisor commitment, we will consider the applicant for the master's program only.

## Additional Standards for Non-Native English Speakers

Official scores from the Test of English as a Foreign Language (TOEFL), International English Language Testing System (IELTS) or Cambridge English: Advanced (CAE) are required of all graduate applicants, regardless of citizenship status, whose native language is not English or who have been educated in countries where English is not the native language. The minimum TOEFL/IELTS/CAE test score requirements for the degree program are:

- **Minimum TOEFL Score (paper-based test)**: 550
- **Minimum TOEFL Score (internet-based test)**: 80
- **Minimum IELTS Score**: 6.5
- **Minimum CAE Score**: 169
- **English Conditional Admission Offered**: In cases where minimum TOEFL/IELTS/CAE scores were not achieved or no English proficiency test was taken, the program may offer English Conditional Admission (ECA) to academically qualified non-native English speakers.

Read the English Language Proficiency (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/additional-standards-for-non-native-english-speakers/english-language-proficiency-ielts-toefl>) policy for more details.

Read the English Conditional Admission (ECA) (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/additional-standards-for-non-native-english-speakers/english-conditional-admission-eca>) policy for more details.

Read the Required Tests for GTA Eligibility (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/additional-standards-for-non-native-english-speakers/required-tests-for-gta-eligibility>) policy for more details.

## Additional Standards for International Applicants

Per Student & Exchange Visitor Program (SEVP) regulation, international applicants must meet all standards for admission before an I-20 or DS-2019 is issued, [per U.S. Federal Register: 8 CFR § 214.3(k)] or is academically eligible for admission and is admitted [per 22 C.F.R. §62]. Read the Additional Standards For International Applicants (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/additional-standards-for-international-applicants>) policy for more details.

## Financial Aid

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# Doctor of Philosophy IN Materials Science - Lockheed Employees Only

## Application Deadlines

- Fall 2018 Priority Deadline: November 3, 2017
- Fall 2018 Final Submission Deadline: June 1, 2018
- Winter 2019 Priority Deadline: June 1, 2018
- Winter 2019 Final Submission Deadline: November 3, 2018
- Spring 2019 Priority Deadline: August 1, 2018
- Spring 2019 Final Submission Deadline: January 7, 2019
- Summer 2019 Priority Deadline: October 1, 2018
- Summer 2019 Final Submission Deadline: April 1, 2019

## Admission Requirements

- **Online admission application**
- **\$65.00 Application Fee**
- **University Minimum Degree and GPA Requirements**
- **Transcripts:** (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/admission-process-and-standards-for-all-applicants/transcripts-and-proof-of-degree>) One official transcript from each post-secondary institution.
- **Letters of Recommendation:** Two (2) letters of recommendation are required. Letters should be submitted by recommenders through the online application.
- **Personal Statement:** A personal statement of at least 300 words is required. Your statement should include information concerning your life, education, experiences, interests and reason for applying to DU.

## Additional Standards for Non-Native English Speakers

Official scores from the Test of English as a Foreign Language (TOEFL), International English Language Testing System (IELTS) or Cambridge English: Advanced (CAE) are required of all graduate applicants, regardless of citizenship status, whose native language is not English or who have been educated in countries where English is not the native language. The minimum TOEFL/IELTS/CAE test score requirements for the degree program are:

- **Minimum TOEFL Score (paper-based test):** 550
- **Minimum TOEFL Score (internet-based test):** 80
- **Minimum IELTS Score:** 6.5
- **Minimum CAE Score:** 169
- **English Conditional Admission Offered:** In cases where minimum TOEFL/IELTS scores were not achieved or no English proficiency test was taken, the Computer Science program may offer English Conditional Admission (ECA) to academically qualified non-native English speakers.

Read the English Language Proficiency (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/additional-standards-for-non-native-english-speakers/english-language-proficiency-ielts-toefl>) policy for more details.

Read the English Conditional Admission (ECA) (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/additional-standards-for-non-native-english-speakers/english-conditional-admission-eca>) policy for more details.

Read the Required Tests for GTA Eligibility (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/additional-standards-for-non-native-english-speakers/required-tests-for-gta-eligibility>) policy for more details.

## Additional Standards for International Applicants

Per Student & Exchange Visitor Program (SEVP) regulation, international applicants must meet all standards for admission before an I-20 or DS-2019 is issued, [per U.S. Federal Register: 8 CFR § 214.3(k)] or is academically eligible for admission and is admitted [per 22 C.F.R. §62]. Read the Additional Standards For International Applicants (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/additional-standards-for-international-applicants>) policy for more details.

## Financial Aid

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## Master of Science in Bioengineering

### Application Deadlines

- Fall 2018 Priority Deadline: November 3, 2017
- Fall 2018 Final Submission Deadline: June 1, 2018
- Winter 2019 Priority Deadline: June 1, 2018
- Winter 2019 Final Submission Deadline: November 3, 2018
- Spring 2019 Priority Deadline: August 1, 2018
- Spring 2019 Final Submission Deadline: January 7, 2019
- Summer 2019 Priority Deadline: October 1, 2018
- Summer 2019 Final Submission Deadline: April 1, 2019

## Admission Requirements

- **Online admission application**
- **\$65.00 Application Fee**

- **University Minimum Degree and GPA Requirements**
- **Transcripts:** (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/admission-process-and-standards-for-all-applicants/transcripts-and-proof-of-degree>) One official transcript from each post-secondary institution.
- **GRE** (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/admission-process-and-standards-for-all-applicants/university-admission-criteria>): The Graduate Record Examination (GRE) is required. Scores must be received directly from the appropriate testing agency by the deadline. The institution code for the University of Denver is 4842.
- **Letters of Recommendation:** Two (2) letters of recommendation are required. Letters should be submitted by recommenders through the online application.
- **Personal Statement:** A personal statement of at least 300 words is required. Your statement should include information concerning your life, education, experiences, interests and reason for applying to DU.
- **Résumé:** The résumé (or C.V.) should include work experience, research, and/or volunteer work.
- **Prerequisites:** Students with a bachelor's degree in Engineering, Chemistry, Biology or Physics is normally required for admission to the MS Bioengineering (ENBI) program. Note that although not an admission requirement, students who are not adequately prepared to succeed in our graduate level courses may choose to complete prerequisite undergraduate courses.

## Additional Standards for Non-Native English Speakers

Official scores from the Test of English as a Foreign Language (TOEFL), International English Language Testing System (IELTS) or Cambridge English: Advanced (CAE) are required of all graduate applicants, regardless of citizenship status, whose native language is not English or who have been educated in countries where English is not the native language. The minimum TOEFL/IELTS/CAE test score requirements for the degree program are:

- **Minimum TOEFL Score (paper-based test):** 550
- **Minimum TOEFL Score (internet-based test):** 80
- **Minimum IELTS Score:** 6.5
- **Minimum CAE Score:** 169
- **English Conditional Admission Offered:** In cases where minimum TOEFL/IELTS/CAE scores were not achieved or no English proficiency test was taken, the Bioengineering program may offer English Conditional Admission (ECA) to academically qualified non-native English speakers.

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# Master of Science in Mechanical Engineering

## Application Deadlines

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- Fall 2018 Final Submission Deadline: June 1, 2018
- Winter 2019 Priority Deadline: June 1, 2018
- Winter 2019 Final Submission Deadline: November 3, 2018
- Spring 2019 Priority Deadline: August 1, 2018
- Spring 2019 Final Submission Deadline: January 7, 2019
- Summer 2019 Priority Deadline: October 1, 2018
- Summer 2019 Final Submission Deadline: April 1, 2019

## Admission Requirements

- **Online admission application**
- **\$65.00 Application Fee**
- **University Minimum Degree and GPA Requirements**
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- **Personal Statement:** A personal statement of at least 300 words is required. Your statement should include information concerning your life, education, experiences, interests and reason for applying to DU.
- **Résumé:** The résumé (or C.V.) should include work experience, research, and/or volunteer work.
- **Prerequisites:** Students with a bachelor's degree in Mechanical Engineering or closely related field is normally required for admission to the MS Mechanical Engineering (ENME) program.

## Additional Standards for Non-Native English Speakers

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## Master of Science in Materials Science

### Application Deadlines

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- Fall 2018 Final Submission Deadline: June 1, 2018
- Winter 2019 Priority Deadline: June 1, 2018
- Winter 2019 Final Submission Deadline: November 3, 2018
- Spring 2019 Priority Deadline: August 1, 2018
- Spring 2019 Final Submission Deadline: January 7, 2019



- Summer 2019 Priority Deadline: October 1, 2018
- Summer 2019 Final Submission Deadline: April 1, 2019

## Admission Requirements

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- **Transcripts:** (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/admission-process-and-standards-for-all-applicants/transcripts-and-proof-of-degree>) One official transcript from each post-secondary institution.
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- **Personal Statement:** A personal statement of at least 300 words is required. Your statement should include information concerning your life, education, experiences, interests and reason for applying to DU.
- **Résumé:** The résumé (or C.V.) should include work experience, research, and/or volunteer work.
- **Prerequisites:** Students with a bachelor's degree in Materials Science, Engineering, Physics, Metallurgy, or Chemistry is normally required for admission to the MS Materials Science (MTSC) program. Note that although not an admission requirement, students who are not adequately prepared to succeed in our graduate level courses may choose to complete prerequisite undergraduate courses.

## Additional Standards for Non-Native English Speakers

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## Financial Aid

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## Master of Science in Bioengineering, Materials Science or Mechanical Engineering - Lockheed Employees Only

### Application Deadlines

- Fall 2018 Priority Deadline: November 3, 2017
- Fall 2018 Final Submission Deadline: June 1, 2018

- Winter 2019 Priority Deadline: June 1, 2018
- Winter 2019 Final Submission Deadline: November 3, 2018
- Spring 2019 Priority Deadline: August 1, 2018
- Spring 2019 Final Submission Deadline: January 7, 2019
- Summer 2019 Priority Deadline: October 1, 2018
- Summer 2019 Final Submission Deadline: April 1, 2019

## Admission Requirements

- **Online admission application**
- **\$65.00 Application Fee**
- **University Minimum Degree and GPA Requirements**
- **Transcripts:** (<http://bulletin.du.edu/graduate/admission-and-enrollment-policies/admission-process-and-standards-for-all-applicants/transcripts-and-proof-of-degree>) One official transcript from each post-secondary institution.

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## Financial Aid

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# Doctor of Philosophy in Materials Science

## Program Requirements

### PhD Residence Requirement

Enrollment in at least six quarters, including at least two consecutive quarters of full-time attendance is required for graduation.

### Exam Structure

1. Each student must pass the **qualifying exam** to obtain official entrance into the PhD program. In consultation with the advisor, students should expect to take the qualifying exam about one year (24 credits) into their academic study. Students must take exams in three subject areas. The design exam is required for all participants, and is an open book exam, where the student will have one week to prepare a written and oral response to an open ended design problem. The other two exams are closed-book written exams and should be related to the student's research area. The exam is offered twice a year: once in the summer interterm (usually in June) and once in the winter interterm (usually in December or early January). The qualifying exam can be retaken only once, and must be completed within one year after the first qualifying exam was attempted.



2. After completion of the qualifying exam and coursework, the student should schedule and take the **comprehensive exam** attended by the student's PhD committee. The student will be expected to make 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. The comprehensive exam can be retaken only once.
3. After successful completion of the qualifying exam and the comprehensive exam, 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 the University's Graduate School guidelines, and must be defended by the student in the final oral defense. The defense committee members will consist of the student's entire PhD committee. The dissertation defense can be retaken only once.

## PhD Students with a Bachelor of Science

### Program Structure:

1. For students entering with a bachelor's degree, 90 credits are required, at least 75 of which must be completed at the University of Denver.
2. A minimum of 48 credits must be at the 4000 or 5000 level and may include as many dissertation research credits as considered appropriate by the advisor.
3. No courses at the 1000 or 2000 level are acceptable.
4. An overall GPA of 3.0 is required for the degree.
5. Any individual grade lower than C- renders the credit unacceptable.
6. Students who have completed the required 90 credits and are still working on the dissertation are eligible for Continuous Enrollment to maintain active student status at the University. Students working on internships are not eligible for Continuous Enrollment.
7. Students must complete all requirements for the doctoral degree no later than eight years after doctoral studies begin.

### Course Requirements:

1. Candidates who hold only a bachelor's degree on entering the doctoral program are expected to **meet all degree requirements of the corresponding master's degree program** (as part of the doctoral requirements).
2. Students are required to take ENME 4950 **Graduate Assessment** in the last quarter of study. NOTE: Students are required to complete a written self-reflection on their thesis and upload the report to Assess-It along with thesis, defense presentation slides, and the completed and signed degree program plan before graduation.
3. PhD students who enter the program with a bachelor's are required to take ENME 4900 **Graduate Professional Development** in the first year (this will be offered once a year; usually in winter quarter).

Code	Title	Credits
<b>Required Core Courses</b>		
ENME 4900	Grad Professional Development (Graduate Professional Development)	1
ENME 4950	Graduate Assessment (Graduate Assessment)	0
<b>Materials Science Core Courses</b>		
ENGR 4200	Introduction to Nanotechnology	4
ENME 4400	Fatigue	4
MTSC 4010	Mechanical Behavior of Materials	4
MTSC 4020	Composite Materials I	4
MTSC 4215	Composite Materials II	4
MTSC 4450	Fracture Mechanics	4
<b>Advanced Math Courses</b>		
ENGR 3620	Advanced Engineering Mathematics	4
ENGR 4300	Advanced Numerical Methods (Advanced Numerical Methods)	4
ENGR 4350	Reliability	4
ENGR 4620	Optimization	4

## PhD Students with a Master of Science

### Program Structure

1. A minimum of 36 credits must be completed at the 4000- or 5000-level, which may include as many research credits as considered appropriate by the advisor.
2. For students entering with a master's degree, up to 45 credits may be transferred and applied to the doctorate degree. In addition, a minimum of 45 credits must be completed at DU. The total number of credits required for the degree is 90.
3. No courses at the 1000- or 2000-level are acceptable.

- An overall GPA of 3.0 is required for the degree.
- Any individual grade lower than C- renders the credit unacceptable.
- Students who have completed the required 90 credits and are still working on the dissertation are eligible for Continuous Enrollment to maintain active student status at the University. Students working on internships are not eligible for Continuous Enrollment.
- A student who holds a master's degree on entering the doctoral program is expected to complete all requirements for the degree no later than seven years after beginning the program.

### Course Requirements

- Students are required to take ENME 4950 **Graduate Assessment** in the last quarter of study. **NOTE:** Students are required to complete a written self-reflection on their thesis and upload the report to Assess-It along with thesis, defense presentation slides, and the completed and signed degree program plan before graduation.
- If a PhD student fails his/her qualifying exam on the first try, he/she will be required to take ENME 4900 **Graduate Professional Development** as well. ENME 4900 will be offered once a year, usually in winter quarter.

## Doctor of Philosophy in Mechanical Engineering

### Program Requirements

#### PhD Residence Requirement

Enrollment in at least six quarters, including at least two consecutive quarters of full-time attendance is required for graduation.

#### Exam Structure

- Each student must pass the **qualifying exam** to obtain official entrance into the PhD program. In consultation with the advisor, students should expect to take the qualifying exam about one year (24 credits) into their academic study. Students must take exams in three subject areas. The design exam is required for all participants, and is an open book exam, where the student will have one week to prepare a written and oral response to an open ended design problem. The other two exams are closed-book written exams and should be related to the student's research area. The exam is offered twice a year: once in the summer interterm (usually in June) and once in the winter interterm (usually in December or early January). The qualifying exam can be retaken only once, and must be completed within one year after the first qualifying exam was attempted.
- After completion of the qualifying exam and coursework, the student should schedule and take the **comprehensive exam** attended by the student's PhD committee. The student will be expected to make 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. The comprehensive exam can be retaken only once.
- After successful completion of the qualifying exam and the comprehensive exam, 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 the University's Graduate School guidelines, and must be defended by the student in the final oral defense. The defense committee members will consist of the student's entire PhD committee. The dissertation defense can be retaken only once.

## PhD Students with a Bachelor of Science

### Program Structure

- For students entering with a bachelor's degree, 90 credits are required, at least 75 of which must be completed at the University of Denver.
- A minimum of 48 credits must be at the 4000- or 5000-level and may include as many dissertation research credits 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.
- Any individual grade lower than C- renders the credit unacceptable.
- Students who have completed the required 90 credits and are still working on the dissertation are eligible for Continuous Enrollment to maintain active student status at the University. Students working on internships are not eligible for Continuous Enrollment.
- Students must complete all requirements for the doctoral degree no later than eight years after doctoral studies begin.

### Course Requirements

- Candidates who hold only a bachelor's degree on entering the doctoral program are expected to **meet all degree requirements of the corresponding master's degree program** (as part of the doctoral requirements).
- Students are required to take ENME 4950 **Graduate Assessment** in the last quarter of study. **NOTE:** Students are required to complete a written self-reflection on their thesis and upload the report to Assess-It along with thesis, defense presentation slides, and the completed and signed degree program plan before graduation.
- PhD students who enter the program with a bachelor's are required to take ENME 4900 **Graduate Professional Development** in the first year (this will be offered once a year; usually in winter quarter).

Code	Title	Credits
<b>Required Core Courses</b>		
ENME 4900	Grad Professional Development (Graduate Professional Development)	1
ENME 4950	Graduate Assessment (Graduate Assessment)	0
<b>Mechanical Engineering Core Mechanical Courses</b>		
ENGR 3630	Finite Element Methods	4
ENME 3545	Mechanisms	4
ENME 3651	Computational Fluid Dynamics	4
ENME 4020	Adv Finite Element Analysis	4
ENME 4520	Intermediate Dynamics (Intermediate Dynamics)	4
ENME 4541	Advanced Mechanics of Materials (Advanced Mechanics of Materials)	4
ENME 4630	Viscous Flow (Viscous Flow)	4
ENME 4670	Advanced Computational Fluid Dynamics	4
ENME 4800	Advanced Topics (ME) (Convective Heat Transfer)	4
<b>Advanced Math Courses</b>		
ENGR 3620	Advanced Engineering Mathematics	4
ENGR 4300	Advanced Numerical Methods	4
ENGR 4350	Reliability	4
ENGR 4620	Optimization	4

## PhD Students with a Master of Science

### Program Structure:

1. A minimum of 36 credits must be at the 4000- or 5000-level and may include as many dissertation research credits as considered appropriate by the advisor. The total number of credits required for the degree is 90.
2. For students entering with a master's degree, up to 45 credits may be transferred and applied to the doctorate degree. In addition, a minimum of 45 credits must be completed at DU. The total number of credits required for the degree is 90.
3. No courses at the 1000- or 2000-level are acceptable.
4. An overall GPA of 3.0 is required for the degree.
5. Any individual grade lower than C- renders the credit unacceptable.
6. Students who have completed the required 90 credits and are still working on the dissertation are eligible for Continuous Enrollment to maintain active student status at the University. Students working on internships are not eligible for Continuous Enrollment.
7. Students must complete all requirements for the doctoral degree no later than seven years after doctoral studies begin.

### Course Requirements:

1. Students are required to take ENME 4950 **Graduate Assessment** in the last quarter of study. **NOTE:** Students are required to complete a written self-reflection on their thesis and upload the report to Assess-It along with thesis, defense presentation slides, and the completed and signed degree program plan before graduation.
2. If a PhD student fails his/her qualifying exam on the first try, he/she will be required to take ENME 4900 **Graduate Professional Development** as well. ENME 4900 will be offered once a year, usually in winter quarter.

## Master of Science in Bioengineering

### Program Structure

1. Every candidate for this degree must complete 45 credits, at least 36 of which must be completed at the University of Denver.
2. A minimum of six 4000-level courses of at least three credits each are required for non-thesis track; four 4000-level courses of at least three credits each are required for thesis track.
3. No courses at the 1000- or 2000-level are acceptable.
4. An overall GPA of 3.0 is required for the degree.
5. Any individual grade lower than C- renders the credit unacceptable.
6. Students who have completed the required 45 credits and are still working on a thesis or project are eligible for Continuous Enrollment to maintain active student status at the University. Students working on internships are not eligible for Continuous Enrollment.
7. Master's degree candidates are expected to complete degree requirements no later than five years after beginning their programs.

## Course Requirements

- Core Courses:** a minimum of nine credits (two courses from the Bioengineering Core Course List plus required courses) for both thesis and non-thesis tracks.
- Required Courses:** All master's students are required to take ENME 4900 **Graduate Professional Development** in the first year (this will be offered once a year; usually in winter quarter) and ENME 4950 **Graduate Assessment** in the last quarter of study. **NOTE:** Students on the **thesis track** are required to complete a written self-reflection on their thesis and upload the report to Assess-It along with thesis, defense presentation slides, and the completed and signed degree program plan before graduation. Students on the **non-thesis track** are required to upload to Assess-It an assembled portfolio that includes reports from at least two course projects or homework from the core courses, a mini-proposal and presentation slides from ENME 4900, along with the completed and signed degree program plan.
- Minor Elective Courses:** minimum of eight credits for thesis track; eight credits for non-thesis track. 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 chosen from regular engineering course offerings numbered 3000 or higher and must be approved by the advisor. Candidates with engineering undergraduate degrees must take graduate-level coursework in biological sciences or chemistry and biochemistry.
- Technical Electives:** a minimum of eight credits for thesis track and 20 credits for non-thesis track. These do not include independent research credits.
  - Technical elective courses are intended to provide bioengineering students an opportunity to take additional course work 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.
  - Students may take one business/management course as a technical elective. Special permission should be obtained in writing from the advisor **PRIOR TO REGISTRATION** if more than one business/management course is taken.
- Advanced Math Requirement:** a minimum of three credits for both thesis track and non-thesis track from Core Course List or advisor approval.
- Thesis Hours:** not allowed for non-thesis track.
- 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, or students completing a thesis, will be exempt from the tool requirement. Candidates with undergraduate degrees from non-engineering majors and completing a non-thesis MS will be required to pass a tool requirement. This will consist of an exam based on the topics in the Fundamentals of Engineering General Exam.

MS ENBI Minimum	Thesis (QH)	Non-Thesis (QH)
Core	9	9
Minor Electives	8	8
Technical Electives	8	20
Advanced Math	3	3
Thesis	0	N/A
Total Credits Required	45	45

Code	Title	Credits
<b>Required Core Courses for MS</b>		
ENME 4900	Grad Professional Development (Graduate Professional Development)	1
ENME 4950	Graduate Assessment (Graduate Assessment)	0
<b>Bioengineering Core Courses</b>		
ENBI 4500	Biofluids	4
ENBI 4510	Biomechanics	4
ENME 4520	Intermediate Dynamics (Intro to Cardiovascular Engineering)	4
ENBI 4800	Adv Topics (Bioengineering) (Computational Biomechanics)	4
<b>Advanced Math Courses</b>		
ENGR 3620	Advanced Engineering Mathematics	4
ENGR 4300	Advanced Numerical Methods (Advanced Numerical Methods)	4
ENGR 4350	Reliability	4
ENGR 4620	Optimization	4

# Master of Science in Materials Science

## MS Program Structure

1. Every candidate for this degree must complete 45 credits, at least 36 of which must be completed at the University of Denver.
2. A minimum of six 4000-level courses of at least three credits each are required for non-thesis track; four 4000-level courses of at least three credits each are required for thesis track.
3. No courses at the 1000- or 2000-level are acceptable.
4. An overall GPA of 3.0 is required for the degree.
5. Any individual grade lower than C- renders the credit unacceptable.
6. Students who have completed the required 45 credits and are still working on a thesis or project are eligible for Continuous Enrollment to maintain active student status at the University. Students working on internships are not eligible for Continuous Enrollment.
7. Master's degree candidates are expected to complete degree requirements no later than five years after beginning their programs.
8. **International students** must enroll in at least eight credits each quarter to maintain full-time status, except during the annual vacation term (usually the summer quarter) or the final quarter of study that requires fewer credits than the minimum full-time enrollment to complete the program. Failure to maintain full-time enrollment is a violation of student status and may result in the termination from the program. Based on the recommendation of the academic advisor, an international student advisor may authorize the student to drop below full-time status for academic reasons specifically permitted under immigration regulations. However, academic authorizations may only be given once per degree level and are usually issued during the first term of study.

## Course Requirements

1. **Core Courses:** a minimum of nine credits (two courses from the Materials Science Core Course List plus required courses) for both thesis and non-thesis tracks.
2. **Required Courses:** All master's students are required to take ENME 4900 **Graduate Professional Development** in the first year (this will be offered once a year; usually in winter quarter) and ENME 4950 **Graduate Assessment** in the last quarter of study. **NOTE:** Students on the **thesis track** are required to complete a written self-reflection on their thesis and upload the report to Assess-It along with thesis, defense presentation slides, and the completed and signed degree program plan before graduation. Students on the **non-thesis track** are required to upload to Assess-It an assembled portfolio that includes reports from at least two course projects or homework from the core courses, a mini-proposal and presentation slides from ENME 4900, along with the completed and signed degree program plan.
3. **Technical Electives:** a minimum of 16 credits for thesis track and 28 credits non-thesis track. These do not include independent research credits.
  - a. Technical electives must be in engineering (bioengineering, mechanical engineering, materials science, etc.) or related areas (mathematics, computer science, physics, chemistry, etc.) and are at the advisor's discretion.
  - b. Students may take one business/management course as a technical elective. Special permission should be obtained in writing from the advisor **PRIOR TO REGISTRATION** if more than one business/management course is taken.
4. **Advanced Math Requirement:** a minimum of three credits for thesis track and six credits for non-thesis track from Core Course List or advisor approval.
5. **Thesis Hours:** not allowed for non-thesis track.

MS MTSC Minimum	Thesis (QH)	Non-Thesis (QH)
Core	9	9
Technical Electives	16	28
Advanced Math	3	6
Thesis	0	N/A
Total Credits Required	45	45

Code	Title	Credits
<b>Required Core Courses for MS</b>		
ENME 4900	Grad Professional Development (Graduate Professional Development)	1
ENME 4950	Graduate Assessment (Graduate Assessment )	0
<b>Materials Science Core Courses</b>		
ENGR 4200	Introduction to Nanotechnology	4
ENME 4400	Fatigue	4
MTSC 4010	Mechanical Behavior of Materials	4
MTSC 4020	Composite Materials I	4
MTSC 4215	Composite Materials II	4
MTSC 4450	Fracture Mechanics	4
<b>Advanced Math Courses</b>		
ENGR 3620	Advanced Engineering Mathematics	4

ENGR 4300	Advanced Numerical Methods (Advanced Numerical Methods)	4
ENGR 4350	Reliability	4
ENGR 4620	Optimization	4

## Master of Science in Mechanical Engineering

### Program Structure

1. Every candidate for this degree must complete 45 credits, at least 36 of which must be completed at the University of Denver.
2. A minimum of six 4000-level courses of at least three credits each are required for non-thesis track; four 4000-level courses of at least three credits each are required for thesis track.
3. No courses at the 1000- or 2000-level are acceptable.
4. An overall GPA of 3.0 is required for the degree.
5. Any individual grade lower than C- renders the credit unacceptable.
6. Students who have completed the required 45 credits and are still working on a thesis or project are eligible for Continuous Enrollment to maintain active student status at the University. Students working on internships are not eligible for Continuous Enrollment.
7. Master's degree candidates are expected to complete degree requirements no later than five years after beginning their programs.
8. **International students** must enroll in at least eight credits each quarter to maintain full-time status, except during the annual vacation term (usually the summer quarter) or the final quarter of study that requires fewer credits than the minimum full-time enrollment to complete the program. Failure to maintain full-time enrollment is a violation of student status and may result in the termination from the program. Based on the recommendation of the academic advisor, an international student advisor may authorize the student to drop below full-time status for academic reasons specifically permitted under immigration regulations. However, academic authorizations may only be given once per degree level and are usually issued during the first term of study.

### Course Requirements

1. **Core Courses:** a minimum of nine credits (two courses from the Mechanical Engineering Core Course List plus required courses) for both thesis and non-thesis tracks.
2. **Required Courses:** All master's students are required to take ENME 4900 **Graduate Professional Development** in the first year (this will be offered once a year; usually in winter quarter) and ENME 4950 **Graduate Assessment** in the last quarter of study. **NOTE:** Students on the **thesis track** are required to complete a written self-reflection on their thesis and upload the report to Assess-It along with thesis, defense presentation slides, and the completed and signed degree program plan before graduation. Students on the **non-thesis track** are required to upload to Assess-It an assembled portfolio that includes reports from at least two course projects or homework from the core courses, a mini-proposal and presentation slides from ENME 4900 along with the completed and signed degree program plan.
3. **Technical Electives:** a minimum of 16 credits for thesis track and 28 credits non-thesis track. These do not include independent research credits.
  - a. Technical electives must be in engineering (bioengineering, mechanical engineering, materials science, etc.) or related areas (mathematics, computer science, physics, chemistry, etc.) and are at the advisor's discretion.
  - b. Students may take one business/management course as a technical elective. Special permission should be obtained in writing from the advisor **PRIOR TO REGISTRATION** if more than one business/management course is taken.
4. **Advanced Math Requirement:** a minimum of three credits for thesis track and six credits for non-thesis track from Core Course List or advisor approval.
5. **Thesis Hours:** not allowed for non-thesis track.
6. **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, or students completing a thesis, will be exempt from the tool requirement. Candidates with undergraduate degrees from non-engineering majors and completing a non-thesis MS will be required to pass a tool requirement. This will consist of an exam based on the topics in the Fundamentals of Engineering General Exam.

MS ENME Minimum	Thesis (QH)	Non-Thesis (QH)
Core	9	9
Technical Electives	16	28
Advanced Math	3	6
Thesis	0	N/A
Total Credits Required	45	45

Code	Title	Credits
<b>Required Core Courses</b>		
ENME 4900	Grad Professional Development (Graduate Professional Development)	1
ENME 4950	Graduate Assessment (Graduate Assessment)	0
<b>Mechanical Engineering Core Courses</b>		



ENGR 3630	Finite Element Methods	4
ENME 3545	Mechanisms	4
ENME 3651	Computational Fluid Dynamics	4
ENME 4020	Adv Finite Element Analysis	4
ENME 4520	Intermediate Dynamics (Intermediate Dynamics)	4
ENME 4541	Advanced Mechanics of Materials (Advanced Mechanics of Materials)	4
ENME 4630	Viscous Flow (Viscous Flow)	4
ENME 4670	Advanced Computational Fluid Dynamics	4
ENME 4800	Advanced Topics (ME) (Convective Heat Transfer)	4
<b>Advanced Math Courses</b>		
ENGR 3620	Advanced Engineering Mathematics	4
ENGR 4300	Advanced Numerical Methods (Advanced Numerical Methods)	4
ENGR 4350	Reliability	4
ENGR 4620	Optimization	4

## Engineering, Bio Courses

### ENBI 4500 Biofluids (4 Credits)

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. Cross listed with ENBI 3500.

### ENBI 4510 Biomechanics (4 Credits)

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. Cross listed with ENBI 3510.

### ENBI 4520 Introduction to Cardiovascular Engineering (4 Credits)

An introduction to cardiovascular mechanics with a focus on the quantitative understanding of the mechanical phenomena that governs the cardiovascular system. Specific topics covered include: basic principles of circulation including macro and micro circulation, soft tissue mechanics, applications to cardiovascular diseases, modelling techniques, clinical and experimental methods, and design of cardiovascular devices. Recommended prerequisites: ENME 2541 and ENME 2661.

### ENBI 4800 Adv Topics (Bioengineering) (1-5 Credits)

Various topics in Bioengineering as announced. May be taken more than once. Prerequisite: varies with offering.

### ENBI 4991 Independent Study (1-5 Credits)

### ENBI 4992 Directed Study (1-5 Credits)

### ENBI 4995 Independent Research (1-18 Credits)

## Engineering, Mechanical Courses

### ENME 3511 Machine Design (3 Credits)

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 and ENME 2541.

### ENME 3545 Mechanisms (4 Credits)

Synthesis, analysis and use of mechanisms. Mechanisms studied include cams, gears and planar linkages, with an emphasis on planar linkages. Prerequisites: ENME 2530 and ENGR 1572.

### ENME 3651 Computational Fluid Dynamics (4 Credits)

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 discretizations 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. Prerequisites: ENME 2671.

### ENME 3661 Mechanical Energy Systems Engineering (4 Credits)

This course covers energy systems engineering analysis from a mechanical and materials engineering perspective. This course covers energy production from traditional energy systems that use fossil fuel combustion such as internal combustion engines, coal-fired plants, and natural gas turbines, to nuclear energy and renewable energy methods such as wind, solar, hydraulic, and geothermal. Lastly, the course will survey emerging technologies for future (21st century) energy systems. Students should have taken at a minimum Thermodynamics, Dynamics, and Fluid Dynamics courses. Prerequisites: ENME 2720, ENME 2510, ENME 2651.

**ENME 3720 Introduction to Aerospace Engineering (4 Credits)**

This course provides an introduction to aerospace engineering analysis and design. In the atmospheric domain, the basics of aerodynamics are covered, followed by flight mechanics. The approach is from a practical perspective in which analysis and design are intertwined. Prerequisites: ENME 2651 and ENME 2720 and ENME 2530.

**ENME 3810 Mechanical Engineering Capstone Laboratory (3 Credits)**

This course is the capstone mechanical engineering laboratory course requiring independent experimental design by student teams. Using experimental equipment available in heat transfer, fluid mechanics, solid mechanics, thermodynamics, and measurement and control, the student team is required to design experiments to solve given problems which will be unique to each team. This course encourages students to develop experimental design and research techniques while continuing to improve skills in fundamental lab notebook keeping, uncertainty analysis in measurements, data acquisition, data analysis, report writing, oral presentations, and laboratory safety and procedures. Prerequisite: ENME 2810.

**ENME 4020 Adv Finite Element Analysis (4 Credits)****ENME 4310 Computational Methods for Mechanics and Materials (4 Credits)**

An introductory course for the general-purpose computational methods in advanced multiscale materials and mechanics. Students learn the fundamentals on the numerical methods used in mechanical and materials engineering. Cross listed with ENME 3310.

**ENME 4360 Elasticity (4 Credits)**

Students will be able to apply the fundamental principles of elasticity to solve two- and three-dimensional mechanical engineering problems involved in modern applications of elastic structures, composite materials, tribology and contact mechanics. Dependence on previous knowledge of solid mechanics, continuum mechanics or mathematics is minimized. The emphasis is placed on the engineering applications of elasticity. Suggested prerequisite: ENME 2541.

**ENME 4400 Fatigue (4 Credits)**

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. Cross listed with ENME 3400.

**ENME 4520 Intermediate Dynamics (4 Credits)**

Development and analysis of dynamic systems through classical and modern approaches. Topics include: reference frames, particle kinematics, Newtonian particle mechanics, Phase Portraits, rigid-body kinematics, Euler's laws, Lagrange's Equations, Lagrange Multipliers, and Kane's Equations. Recommended prerequisites: MATH 2070 and MATH 2080.

**ENME 4541 Advanced Mechanics of Materials (4 Credits)**

This is a second-level course in mechanics of materials with an emphasis on techniques that are useful for mechanical design. Topics may include energy methods, non-symmetrical and nonlinear bending, shear and torsion of closed and open sections, beams in elastic foundations, membrane stress in axisymmetric shells, axisymmetric bending of cylindrical shells, thick-walled cylinders and disks, curved beams, and elastic stability. Recommended prerequisite: ENME 2541.

**ENME 4630 Viscous Flow (4 Credits)**

Course covers the fundamentals of fluid mechanics from an advanced point of view with emphasis on the mathematical treatment of viscous-flow phenomena. Topics cover the Navier-Stokes equations and its exact and similarity solutions, laminar boundary layer theory, free-shear flows, and the phenomena of instability and transition to turbulence. Recommended prerequisite: ENME 2661.

**ENME 4650 Adv. Fluid Dynamics (4 Credits)**

Physical properties of liquids and gases; turbulence and closure models; surface waves and instabilities; non-Newtonian fluid behavior; conformal mapping and airfoil theory.

**ENME 4660 Micro Heat Exchangers (4 Credits)**

Explores the advanced 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 Credits)**

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.

**ENME 4671 Convective Heat Transfer (4 Credits)**

The objective of this course is to examine the physical phenomena associated with heat transfer in the presence of fluid flow. We will develop a mathematical description of the processes (fluid flow and heat transfer) for laminar and turbulent flows for both internal and external situations. Exposure to the fundamentals of fluid mechanics and heat transfer is expected before taking this course.

**ENME 4800 Advanced Topics (ME) (0-5 Credits)**

Determined by interest and demand. May be taken more than once for credit.

**ENME 4900 Grad Professional Development (1 Credit)**

This course is required for all MME MS graduate students and all MME PhD graduate students who enter with a BS or enter with an MS but fail their first qualifying exam. One of our objectives is for all graduating students to have good written and verbal communication skills. This course is set up to meet those objectives. During this course, students write a mini-proposal and/or literature review. Students follow guidelines for a funding agency (e.g. NSF or NIH) for the mini-proposal. If students have a research advisor, students can coordinate with their advisor. If students do not have a research advisor, students may pick a topic that most interests them. Both a written proposal and an oral presentation are required of all students. Graduate standing is required.

**ENME 4950 Graduate Assessment (0 Credits)**

This graduate assessment course is required for all MME graduate students to be taken in their last quarter. All required assessment materials are uploaded to DU Assessment to meet the course requirements. Students will receive emails through the DU Assessment system notifying you of what is required to be uploaded.

**ENME 4991 Independent Study (1-10 Credits)****ENME 4992 Directed Study (1-10 Credits)****ENME 4995 Independent Research (1-16 Credits)****ENME 5991 Independent Study (1-10 Credits)****ENME 5995 Independent Research (1-16 Credits)****Engineering Courses****ENGR 3210 Intro Nano-Electro-Mechanics (4 Credits)**

Familiarize science and engineering students with the electromechanical aspects of the emerging field of Nanotechnology (NEMS). NEMS is a relatively new and highly multidisciplinary field of science and technology with applications to state of the art and future sensors, actuators, and electronics. Starting with an overview of nanotechnology and discussion on the shifts in the electromechanical behavior and transduction mechanisms when scaling the physical dimensions from centimeters to micro-meters and then down to nanometers. Several electromechanical transduction mechanisms at the micro and nanoscale are presented and discussed in an application based context. New electromechanical interactions appearing in the nano and molecular scale, such as intra-molecular forces and molecular motors, are discussed. A detailed discussion and overview of nanofabrication technologies and approaches are also provided. Cross listed with ENGR 4210. Prerequisite: must be an engineering or science major of at least junior standing.

**ENGR 3340 Product Development and Market Feasibility (4 Credits)**

In this course, students gain knowledge of designing products for market success by developing a product and optimizing its design for specific mass manufacturing technologies. Students gain experience through the design development process including market feasibility research, human-centered design, brainstorming and ideating new concepts, refinement through design iteration, and constructing alpha and beta prototypes that are designed with mass manufacturing considerations. Projects are based upon real world new product development principles. Students learn and practice the fundamentals of design thinking, design process, and entrepreneurship.

**ENGR 3510 Renewable and Efficient Power and Energy Systems (4 Credits)**

This course introduces the current and future sustainable electrical power systems. Fundamentals of renewable energy sources and storage systems are discussed. Interfaces of the new sources to the utility grid are covered. Prerequisite: ENEE 2021.

**ENGR 3520 Introduction to Power Electronics (4 Credits)**

This covers fundamentals of power electronics. We discuss various switching converters topologies. Basic knowledge of Efficiency and small-signal modeling for the DC-DC switching converters is covered. Furthermore, magnetic and filter design are introduced. Prerequisites: ENEE 2211 and ENGR 3722.

**ENGR 3525 Power Electronics and Renewable Energy Laboratory (1 Credit)**

In this course the fundamentals of switching converters and power electronics in a real laboratory set-up are covered. The course incorporates hardware design, analysis, and simulation of various switching converters as a power processing element for different energy sources. The energy sources are power utility, batteries, and solar panels. Prerequisite: ENGR 3520.

**ENGR 3540 Electric Power Systems (4 Credits)**

This course covers methods of calculation of a comprehensive idea on the various aspects of power system problems and algorithms for solving these problems. Prerequisite: ENGR 3530.

**ENGR 3550 Introduction to Machine Drive Control (4 Credits)**

This course provides the basic theory for the analysis and application of adjustable-speed drive systems employing power electronic converters and ac or dc machines. Prerequisites: ENGR 3520 and ENGR 3530.

**ENGR 3620 Advanced Engineering Mathematics (4 Credits)**

Applied mathematics for engineers. Systems and series solutions of ordinary differential equations, Fourier analysis, partial differential equations, linear algebra, vector calculus, special functions, unconstrained and combinatorial optimization, and applied probability and statistics. Cross listed with ENGR 3610. Prerequisites: MATH 2070 and MATH 2080.

**ENGR 3621 Advanced Engineering Mathematics (4 Credits)**

Applied mathematics for engineers. Topics include vector spaces, normed vector spaces, inner product spaces, linear transformations, finite-dimensional linear transformations, linear operators, finite-dimensional linear operators, linear differential systems, linear difference systems, orthogonal transformations, amplitude estimation, fundamentals of real and functional analysis, and introduction to partial differential equations, and applications to engineering systems.

**ENGR 3630 Finite Element Methods (4 Credits)**

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. Prerequisites: ENME 2541 AND ENGR 1572.

**ENGR 3650 Probability and Statistics for Engineers (4 Credits)**

This course covers quantitative analysis of uncertainty and decision analysis in engineering. It covers the fundamentals of sample space, probability, random variables (discrete and continuous), joint and marginal distributions, random sampling and point estimation of parameters. It also covers statistical intervals, hypotheses testing and simple linear regression. The course includes applications appropriate to the discipline. Prerequisite: MATH 1953.

**ENGR 3721 Controls (3,4 Credits)**

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. Prerequisites: ENEE 2021, ENGR 3610 or permission of instructor.

**ENGR 3722 Control Systems Laboratory (1 Credit)**

This laboratory course serves as supplement to ENGR 3721. It aims at providing "hands on" experience to students. It includes experiments on inverted pendulum, gyroscopes, motor control, feedback controller design, time-domain and frequency domain. Corequisite: ENGR 3721.

**ENGR 3730 Robotics (3 Credits)**

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. Cross listed with ENGR 4730. Prerequisites: ENME 2520 and MATH 2060 or MATH 2200 or permission of instructor.

**ENGR 3731 Robotics Lab (1 Credit)**

Laboratory that complements the analysis, design, modeling and application of robotic manipulators. Implementation of the mathematical structures required to support robot operation. 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. Corequisite: ENGR 3730 or permission of instructor.

**ENGR 3742 LabVIEW Programming, a primer for certification as an Applications Developer (4 Credits)**

The LabVIEW course covers numeric, Boolean, and string controls; programming structures include loops, sequences, formula, and case structures. VISA (virtual instrumentation and software structure) and SCPI (standard commands for programmable instruments) are used to control test equipment and acquire data via the GPIB (general purpose interface bus, IEEE488 standard). Vis (virtual instruments) for data acquisition and analysis are developed utilizing mathematical, signal processing, and statistical LabVIEW programming modules. LabVIEW structures will be used to mathematically model and solve second order differential equations and Laplace transforms.

**ENGR 3800 Topics (ENGR) (1-4 Credits)**

Special topics in engineering as announced. May be taken more than once. Prerequisite: varies with offering.

**ENGR 3900 Engineering Internship (0-4 Credits)**

Students in engineering may receive elective credit for engineering work performed for engineering employers with the approval of the chair or associate chair of the department. At the end of the term, a student report on the work is required, and a recommendation will be required from the employer before a grade is assigned. Junior, senior, or graduate status in engineering is normally required. May not be used to satisfy technical requirements. May be taken more than one for a maximum of 6 quarter hours. Prerequisite: permission of instructor.

**ENGR 4100 Instrumentation and Data Acquisition (4 Credits)**

This course examines different instrumentation techniques and describes how different measurement instruments work. Measurement devices include length, speed, acceleration, force, torque, pressure, sound, flow, temperature, and advanced systems. This course also examines the acquisition, processing, transmission and manipulation of data. Final project or paper. Cross listed with ENGR 3100. Prerequisites: PHYS 1213 OR PHYS 1214.

**ENGR 4200 Introduction to Nanotechnology (4 Credits)**

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. Multiscale modeling based on finite element simulations, Monte Carlo methods, molecular dynamics and quantum mechanics calculations are briefly addressed. Most importantly, students should obtain appreciation of developments in nanotechnology outside their present area of expertise. Cross listed with ENGR 3200.

**ENGR 4210 Introduction to Nano-Electro-Mechanical-Systems (4 Credits)**

This course familiarizes science and engineering students to the electromechanical aspects of the emerging field of Nanotechnology (NEMS). NEMS is a relatively new and highly multidisciplinary field of science and technology with applications in the state of the art and future sensors, actuators, and electronics. This course starts with an overview of nanotechnology and discussion on the shifts in the electromechanical behavior and transduction mechanisms when scaling the physical dimensions from centimeters to micro-meters and then down to nanometers. Several electromechanical transduction mechanisms at the micro and nanoscale are presented and discussed in an application based context. New electromechanical interactions appearing in the nano and molecular scale, such as intra-molecular forces and molecular motors, are discussed. A detailed discussion and overview of nanofabrication technologies and approaches are also provided. Cross listed with ENGR 3210.

**ENGR 4215 Nanoscale Electromechanical Systems and Nanofabrication Laboratory (4 Credits)**

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

**ENGR 4220 Introduction to Micro-Electro-Mechanical-Systems (4 Credits)**

This course introduces students to the multi-disciplinary field of Micro-Electro-Mechanical-Systems (MEMS) technology. MEMS and Microsystem technology is the integration of micro-scale electro-mechanical elements, sensors, actuators, and electronics on a common substrate or platform through semiconductor microfabrication technologies. The course gives a brief overview of the involved physical phenomena, electromechanical transduction mechanisms, design principles, as well as fabrication and manufacturing technologies. Cross listed with ENGR 3220.

**ENGR 4300 Advanced Numerical Methods (4 Credits)**

Fundamental and advanced numerical methods to approximate mathematical problems for engineering applications using modern software such as Matlab. Topics include numerical differentiation and integration, solution to linear and non-linear equations, ordinary and partial differential equations, and initial, boundary, and eigen value problems. Recommended prerequisite: MATH 2070.

**ENGR 4350 Reliability (4 Credits)**

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. Cross listed with ENGR 3350.

**ENGR 4530 Intro to Power and Energy (4 Credits)**

Basic concepts of AC systems, single-phase and three-phase networks, electromechanical energy conversion, electric power generation, transformers, transmission lines, AC machinery, DC motors, and contemporary topics in power and energy conversion. Cross listed with ENGR 3530.

**ENGR 4545 Electric Power Economy (4 Credits)**

This course covers economy aspects of electric power industry and the implications for power and energy engineering in the market environment. Cross listed with ENGR 3545.

**ENGR 4550 Probabilistic Methods in Electric Power Systems (4 Credits)**

The course covers techniques for probabilistic power system analysis and design, power system reliability, probabilistic structural design and analysis of transmission lines, analysis and assessment of transmission line reliability, probability-based power system design criteria, probabilistic load-flow studies and probabilistic power system stability. Prerequisites: ENGR 3540 or equivalent; permission of instructor; knowledge of MATLAB/Simulink is required.

**ENGR 4560 Power Generation Operation and Control (4 Credits)**

This course covers economic dispatch of thermal units and methods of solution; transmission system effects; generate with limited energy supply; production cost models; control of generation; interchange of power and energy; power system security; state estimation in power systems; optimal power flow. Prerequisite: ENGR 4540.

**ENGR 4590 Power System Protection (4 Credits)**

This course covers methods of calculation of fault currents under different types of fault; circuit breakers, current transformers, potential transformers; basic principles of various types of relays; applications of relays in the protection of generator, transformer, line, and bus, etc. Prerequisite: ENGR 4540.

**ENGR 4620 Optimization (3,4 Credits)**

Engineering problems will be formulated as different programming problems to show the wide applicability and generality of optimization methods. The development, application, and computational aspects of various optimization techniques will be discussed with engineering examples. The application of nonlinear programming techniques will be emphasized. A design project will be assigned.

**ENGR 4730 Introduction to Robotics (4 Credits)**

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. Cross listed with ENGR 3730. Prerequisites: ENME 2520 and MATH 2060 or MATH 2200 or instructor approval.



**ENGR 4735 Linear Systems (4 Credits)**

This course focuses on linear system theory in time domain. It emphasizes linear and matrix algebra, numerical matrix algebra and computational issues in solving systems of linear algebraic equations, singular value decomposition, eigenvalue-eigenvector and least-squares problems, linear spaces and linear operator theory. It studies modeling and linearization of multi-input/multi-output dynamic physical systems, state-variable and transfer function matrices, analytical and numerical solutions of systems of differential and difference equations, structural properties of linear dynamic physical systems, including controllability, observability and stability. It covers canonical realizations, linear state-variable feedback controller and asymptotic observer design, and the Kalman filter. Cross listed with ENGR 3735. Prerequisites: ENGR 3610, ENGR 3721/3722, or permission of the instructor.

**ENGR 4740 Adaptive Control Systems (4 Credits)**

Theoretical and application aspects of robust adaptive control design for uncertain dynamical systems. Topics include: parameter estimation, stability, model reference adaptive systems, self-tuning regulators, gain scheduling, design for robustness against unmodeled dynamics and disturbance signals. Examples will be given from aerospace engineering (changes in the dynamics of aircraft), process control, and robotics. Modern alternatives to traditional adaptive control will be discussed (switching multi-model/multi-controller adaptive schemes). Prerequisites: ENEE 3111, ENGR 3610, and ENGR 3721, or permission of instructor. Familiarity with MATLAB/Simulink.

**ENGR 4745 Adv Non-Linear Control System (4 Credits)**

Nonlinear system analysis methods: Existence of solutions of ODEs, uniqueness, continuity, compactness, fixed point, linearization, metric spaces, Contraction Mapping Theorem, Gronwall-Bellman lemma. Phase plane analysis; Limit Cycles. Lyapunov stability of autonomous and non-autonomous systems. Circle criterion, absolute stability, Popov criterion. Passivity and Lyapunov stability. Input-to-State stability. Small Gain Theorem. Describing functions. Nonlinear control system synthesis methods: Passivity-based control. Stability via Feedback Linearization. Lie derivatives.

**ENGR 4750 Networked Control Systems (4 Credits)**

Fundamental tools and recent advances in networked control. Topics include the control of multi-agent networks found in multi-vehicle coordination, control of sensor networks, unmanned vehicles, and energy systems. Network models, distributed control and estimation, distributed control under limited communications and sensing, formation control, coverage control in mobile sensor networks. Prerequisites: linear algebra, linear control systems, differential equations, familiarity with MATLAB, or permission of instructor.

**ENGR 4755 Optimal Control (4 Credits)**

Introduction to optimal control theory (control laws that maximize a specified measure of a dynamical system's performance). Topics include: optimality conditions and constraints; calculus of variations; review of mathematical programming (Lagrange multipliers, convexity, Kuhn-Tucker theorem); Pontryagin's maximum principle (constraints, Hamiltonians, bang-bang control); dynamic programming and Linear Quadratic Regulation (Riccati, Hamilton-Jacobi equation). Prerequisites: ENGR 3721 (Controls) and ENGR 3735/4735 (Linear Systems) or equivalent courses.

**ENGR 4760 Multivariable Control (4 Credits)**

Multivariable aspects of control (systems with multiple actuators and sensors); performance analysis of feedback control systems; sensitivity; robustness and stability margins; disturbance attenuation; design tradeoffs; singular value; characteristic locus. Modern H-infinity control theory and 'mu' synthesis-based robust control design techniques. Enforced Prerequisites and Restrictions ENGR 3721 (Controls) and ENGR 4735 (Linear Systems at a graduate level) or equivalents.

**ENGR 4810 Advanced Topics (ENGR) (1-5 Credits)****ENGR 4885 Graduate Project for non-Thesis Option Master's Degree (1-4 Credits)**

This course is required for all Master of Science graduate students with major in Electrical Engineering, Computer Engineering, and Mechatronic Systems Engineering, who choose the non-thesis option. The student will be supervised by his or her faculty advisor to conduct original and independent research with project topic closely related to the student's depth requirement of the specialization area. The student will deliver a final comprehensive project report and an oral defense for the project. The examination committee for the Master's project shall consist of at least two faculty members.

**ENGR 4991 Independent Study (1-5 Credits)****ENGR 4992 Directed Study (1-10 Credits)****ENGR 4995 Independent Research (1-16 Credits)****ENGR 5991 Independent Study (1-10 Credits)****ENGR 5995 Independent Research (1-16 Credits)****Materials Science Courses****MTSC 4010 Mechanical Behavior of Materials (4 Credits)**

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. Cross listed with MTSC 3010.

**MTSC 4020 Composite Materials I (4 Credits)**

An introduction to composite materials. Properties of fibers and matrices, fiber architecture, elastic properties of laminae and laminates, interface in composites. Cross listed with MTSC 3020.



**MTSC 4215 Composite Materials II (4 Credits)**

A continuation of MTSC 4210: Strength and toughness of composites, thermal behavior, fabrication methods, examples of applications. Prerequisite: MTSC 4210.

**MTSC 4450 Fracture Mechanics (4 Credits)**

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. Cross listed with MTSC 3450.

**MTSC 4800 Advanced Topics (MTSC) (1-5 Credits)**

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 Credit)**

Weekly presentations by graduate students, faculty, outside speakers, etc., on research in progress or other topics of interest.

**MTSC 4991 Independent Study (1-10 Credits)****MTSC 4992 Directed Study (1-10 Credits)****MTSC 4995 Independent Research (1-16 Credits)****MTSC 5995 Independent Research (1-16 Credits)**