ENGINEERING

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Master's and Doctoral Degrees

Why study engineering at the University of Denver?

The University of Denver's Daniel Felix Ritchie School of Engineering and Computer Science is creating the future of technology by providing a graduate education emphasizing cross-disciplinary knowledge. 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 contain state-of-the-art equipment and software to support research in biomedical engineering, advanced materials, robotics, mechanical design, and AI/machine learning, 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.

The general engineering graduate student can choose courses from mechanical engineering, electrical engineering, computer engineering, computer science, and bioengineering.

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 Tech Center, site of many top technology companies. The Department of Mechanical 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, many 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. We also can provide hybrid and Zoom-based course options.

The master's program offers 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 a special status student (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

The following are our general engineering degrees. Please see the Mechanical and Materials Engineering Programs for our other graduate engineering degrees.

- Master of Science in Engineering (MS ENGE)
- Master of Science in Engineering with a Concentration in Engineering Management (MS ENGE (CM))
- Doctor of Philosophy in Engineering (PhD ENME)
- Doctor of Philosophy in Biomedical Engineering

Doctor of Philosophy in Engineering

The Doctor of Philosophy in Engineering (PhD ENGE) program prepares students to contribute to the advancement of science, engineering, and technology through independent research. The PhD students of the 21st century may pursue academic, research, or industry careers. Individualized plans of study are 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 interdisciplinary Engineering PhD program offers opportunities for a student to develop a plan of study combining engineering and a complementary discipline (e.g. natural sciences). In the plan of study, coursework in the complementary discipline can be included up to the maximum number of technical elective credits. The student's plan of study must be approved by the PhD committee and the department chair. When the student is completing research and coursework in a complementary discipline, the student's PhD committee must include a faculty member from the related department or division/school.

For a part-time student who is working in an industry position, a topic related to the job function may be acceptable as the dissertation research topic. Furthermore, a student may request for a qualified staff member at the place of employment to serve as a special committee member on the dissertation committee.

Doctor of Philosophy in Biomedical Engineering

The Doctor of Philosophy in Biomedical Engineering (PhD BME) program combines cross-disciplinary course work in engineering and life sciences. It trains students to carry out independent research in fields related to human health and well-being. The training combines engineering principles with sciences to further our understanding of health-related problems and to design and create novel methods, devices, and software to bring innovative solutions to these problems.

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 technical elective requirement addressing the student's specific interests.

A Master of Science in Engineering with a concentration in Management (CM) is also offered (see below).These engineering and management courses 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.

Master of Science in Engineering with a Concentration in Engineering Management

The degree of Master of Science in Engineering allows students to pursue a concentration in engineering management (MS ENGE(CM)).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 RSECS and the Daniels College of Business, the program provides the relevant content for graduates to lead technology enterprises. Candidates for the degree of master of science with a concentration in management will be on the non-thesis track only.

Doctor of Philosophy in Biomedical Engineering

Degrees and GPA Requirements

Bachelors degree: All graduate applicants must hold an earned baccalaureate from a regionally accredited college or university or the recognized equivalent from an international institution.

University GPA requirement: The minimum grade point average for admission consideration for graduate study at the University of Denver must meet one of the following criteria:

- A cumulative 2.5 on a 4.0 scale for the baccalaureate degree.
- A cumulative 2.5 on a 4.0 scale for the last 60 semester credits or 90 quarter credits (approximately two years of work) for the baccalaureate degree.
- An earned master's degree or higher from a regionally accredited institution or the recognized equivalent from an international institution supersedes the minimum GPA requirement for the baccalaureate.
- A cumulative GPA of 3.0 on a 4.0 scale for all graduate coursework completed for applicants who have not earned a master's degree or higher.

Prerequisites

- A bachelor's degree in engineering or related field from a regionally accredited college or university is required for admission to the program.

Standardized Test Scores

- GRE scores are optional for admission to this program. Applications submitted without scores will receive full consideration. Every application undergoes a comprehensive evaluation, including a careful review of all application materials.
- If you choose to submit test scores, you may upload your Test Taker Score Report PDF, which is considered unofficial. Official scores must be received directly from the appropriate testing agency upon admission to the University of Denver. The ETS institution code to submit GRE scores to the University of Denver is 4842.

Other Required Materials

PhD applicants should contact faculty to find a research advisor BEFORE submitting the application. Applications without a research advisor commitment may be considered for a master's program only.

English Language Proficiency Test Score Requirements

The minimum TOEFL/IELTS/C1 Advanced/Duolingo English Test score requirements for this degree program are:

- Minimum TOEFL Score (Internet-based test): 80
- Minimum IELTS Score: 6.5
- Minimum C1 Advanced Score: 176
- Minimum Duolingo English Test Score: 115

Doctor of Philosophy in Engineering

Degrees and GPA Requirements

Bachelors degree: All graduate applicants must hold an earned baccalaureate from a regionally accredited college or university or the recognized equivalent from an international institution.

University GPA requirement: The minimum grade point average for admission consideration for graduate study at the University of Denver must meet one of the following criteria:

- A cumulative 2.5 on a 4.0 scale for the baccalaureate degree.
- A cumulative 2.5 on a 4.0 scale for the last 60 semester credits or 90 quarter credits (approximately two years of work) for the baccalaureate degree.
- An earned master's degree or higher from a regionally accredited institution or the recognized equivalent from an international institution supersedes the minimum GPA requirement for the baccalaureate.
- A cumulative GPA of 3.0 on a 4.0 scale for all graduate coursework completed for applicants who have not earned a master's degree or higher.

Prerequisites

- Students with a master's degree in Engineering or closely related areas may apply for the PhD program in Engineering (ENGR). 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 ENGR 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.

Other Required Materials

- 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.

English Language Proficiency Test Score Requirements

The minimum TOEFL/IELTS/C1 Advanced/Duolingo English Test score requirements for this degree program are:

- Minimum TOEFL Score (Internet-based test): 80
- Minimum IELTS Score: 6.5
- Minimum C1 Advanced Score: 176
- Minimum Duolingo English Test Score: 115

Master of Science in Engineering

Degrees and GPA Requirements

Bachelors degree: All graduate applicants must hold an earned baccalaureate from a regionally accredited college or university or the recognized equivalent from an international institution.

University GPA requirement: The minimum grade point average for admission consideration for graduate study at the University of Denver must meet one of the following criteria:

- A cumulative 2.5 on a 4.0 scale for the baccalaureate degree.
- A cumulative 2.5 on a 4.0 scale for the last 60 semester credits or 90 quarter credits (approximately two years of work) for the baccalaureate degree.

- An earned master's degree or higher from a regionally accredited institution or the recognized equivalent from an international institution supersedes the minimum GPA requirement for the baccalaureate.
- A cumulative GPA of 3.0 on a 4.0 scale for all graduate coursework completed for applicants who have not earned a master's degree or higher.

Prerequisites

- Students with a bachelor's degree in Engineering, Mathematics, Chemistry, Biology or Physics is normally required for admission to the MS Engineering with or without the concentration in Management (ENGR/ENGR CM) programs. 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.

English Language Proficiency Test Score Requirements

The minimum TOEFL/IELTS/C1 Advanced/Duolingo English Test score requirements for this degree program are:

- Minimum TOEFL Score (Internet-based test): 80
- Minimum IELTS Score: 6.5
- Minimum C1 Advanced Score: 176
- Minimum Duolingo English Test Score: 115

Doctoral Programs

Doctor of Philosophy in Biomedical Engineering

Degree requirements

Minimum number of credits required for the degree: 90 (45 for those who enter with a Master of Science degree)

PhD Students with a Bachelor of Science Degree 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.

1. 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.
2. No courses at the 1000- or 2000-level are acceptable.
3. An overall GPA of 3.0 is required for the degree.
4. Any individual grade lower than C- renders the credit unacceptable.
5. 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.
6. Students must complete all requirements for the doctoral degree no later than eight years after doctoral studies begin.

Ph.D. Residence Requirement:

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

Program Requirement Exam Structure

1. Each student must pass the **qualifying exam** to continue in the PhD program. A "mock research proposal" in an area related to the student's research. The student is expected to schedule this exam after 4 quarters. The qualifying exam can be retaken only once.
2. After completion of the qualifying exam and coursework, the student should schedule and take the **dissertation proposal exam**. The student will develop a research proposal (NSF or NIH format) for their proposed doctoral research project and orally defend their proposal. The dissertation proposal needs to be completed at least one year before the dissertation defense. The dissertation proposal exam can be retaken only once.
3. After successful completion of the qualifying exam and the dissertation proposal 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 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.

Course requirements

Code	Title	Credits
Required Courses:		
ENBI 4600	Biomedical Engineering: Technology, Research, and Design	4
ENBI 4610	Experimental Design in Biomedical Sciences	4
ENGR 4300	Advanced Numerical Methods	4
ENME 4900	Grad Professional Development	1
Elective Core:		**8**

• Candidates with an engineering undergraduate degree and/or a master's degree in engineering must take graduate-level coursework in biological sciences or chemistry and biochemistry with the approval of their advisor. Biological sciences, chemistry, and biochemistry courses listed under technical electives below are acceptable but they can count only once, either as elective core course or technical core course but not both simultaneously.

• Candidates without an engineering degree must take courses in engineering with the following prefixes ENCE, ENEE, ENME numbered 3000 or higher and must be approved by the advisor.		
Technical Electives		**4**
Technical Electives for those with an engineering degree:		
BIOL 3241	Anatomy and Physiology of the Skeletal, Nervous and Muscular systems	
BIOL 3242	Human Anatomy and Physiology - Systems of homeostasis	
BIOL 3640	Introductory Neurobiology	
BIOL 3647	Neuroscience of Movement	
CHEM 3811	Biochemistry-Proteins	
ENBI 4500	Biofluids	
ENBI 4510	Biomechanics	
ENBI 4520	Introduction to Cardiovascular Engineering	
ENBI 4530	Biomechanics of Human Movement	
ENBI 4630	Biomaterials	
ENBI 4800	Adv Topics (Bioengineering)	
ENGR 3630	Finite Element Methods	
ENGR 3450	Biosensing Technology	
ENGR 3455/4455	Fluorescence and Its Applications in Biomedical Sensors	
ENGR 4350	Reliability	
ENGR 4620	Optimization	
Technical Electives for those with a non-engineering degree:		
ENBI 4500	Biofluids	
ENBI 4510	Biomechanics	
ENBI 4520	Introduction to Cardiovascular Engineering	
ENBI 4530	Biomechanics of Human Movement	
ENBI 4620	Bioelectronics	
ENBI 4630	Biomaterials	
ENBI 4800	Adv Topics (Bioengineering)	
ENGR 3450	Biosensing Technology	
ENGR 3455/4455	Fluorescence and Its Applications in Biomedical Sensors	
ENGR 3620	Advanced Engineering Mathematics - Corporate	
ENGR 3630	Finite Element Methods	
ENGR 4100	Instrumentation and Data Acquisition	
ENGR 4350	Reliability	
ENGR 4620	Optimization	
Research Coursework		
ENGR 5995	Independent Research	20
Total Credits		**45**

Doctor of Philosophy in Engineering

Program Requirements

Exam Structure:

1. Each student must pass the **qualifying exam** to continue in 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 ~~prior to~~ the first qualifying ~~comprehensive~~ 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 a 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 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 Residence Requirement

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

PhD Students with a Bachelor of Science Degree

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.
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 dissertation and provide their dissertation, 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 is offered once a year; usually in winter quarter).

Code	Title	Credits
Required Core Courses		
ENME 4900	Grad Professional Development	1
ENME 4950	Graduate Assessment	0
Mechanical Engineering Core Courses		
ENGR 3630	Finite Element Methods	4
ENGR 4730	Introduction to Robotics	4
ENME 3545	Mechanisms	4
ENME 3651	Computational Fluid Dynamics	4
ENME 4020	Adv Finite Element Analysis	4
ENME 4360	Elasticity	4
ENME 4520	Intermediate Dynamics (Intermediate Dynamics)	4
ENME 4541	Advanced Mechanics of Materials	4
ENME 4630	Viscous Flow	4
ENME 4670	Advanced Computational Fluid Dynamics	4
ENME 4671	Convective Heat Transfer	4
ENME 4800	Advanced Topics (ME)	4
Bioengineering Core Courses		**4**
ENBI 4500	Biofluids	4
ENBI 4510	Biomechanics	4
ENBI 4520	Introduction to Cardiovascular Engineering	4
ENBI 4800	Adv Topics (Bioengineering)	4
Materials Science Core Courses		
ENGR 4200	Introduction to Nanotechnology	4
ENME 4310	Computational Methods for Mechanics and Materials	4

ENME 4400	Fatigue	4
MTSC 4020	Composite Materials I	4
MTSC 4215	Composite Materials II	4
MTSC 4450	Fracture Mechanics	4
Electrical & Computer Engineering - Any 4XXX level ENEE or ENCE course		
Advanced Math Courses		
ENGR 3621	Advanced Engineering Mathematics	4
ENGR 4300	Advanced Numerical Methods	4
ENGR 4350	Reliability	4
ENGR 4620	Optimization	4
ENGR 4765	Robot Control	4

PhD Students with a Master of Science

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.
4. An overall GPA of 3.0 is required for the degree.
5. Any individual grade lower than C- renders the credit unacceptable.
6. 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:

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 dissertation and provide their dissertation, defense presentation slides, and the completed and signed degree program plan before graduation.
2. If a PhD student fails the qualifying exam on the first try, they 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's Degree Program

Master of Science in Engineering

Program Structure (non-management option)

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.
7. Master's degree candidates are expected to complete degree requirements no later than five years after beginning their programs. These programs are designed to be completed in about six quarters if two courses (eight credits) are taken each quarter.

Course Requirements

1. **Core Courses**: a minimum of nine credits (two courses from ENME, MTSC, ENBI or ECE Core Course List; no more than one course from a single discipline) plus the required courses.
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 provide their thesis, defense presentation slides, and the completed and signed degree program plan before graduation. Students on the **non-thesis track** are required to provide 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 4950 along with the completed and signed degree program plan.
3. **Technical Electives**: a minimum of 16 credits for thesis track and 28 credits for 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. 50% or more of the technical elective credits must be in engineering.
   b. A 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 the 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 ENGE Thesis/Non-thesis **Minimum** Credit Requirements

Requirement	Thesis	Non-Thesis	CM
Core	9	9	NA
Technical Electives	16	28	NA
Advanced Math	3	6	NA
Thesis	0	NA	NA
Total Credits Required	45	45	NA

Code	Title	Credits
Required Core Courses		
ENME 4900	Grad Professional Development	1
ENME 4950	Graduate Assessment	1
Mechanical Engineering Core Courses		
ENGR 3630	Finite Element Methods	4
ENGR 4730	Introduction to Robotics	4
ENME 3545	Mechanisms	4
ENME 3651	Computational Fluid Dynamics	4
ENME 4020	Adv Finite Element Analysis	4
ENME 4360	Elasticity	4
ENME 4520	Intermediate Dynamics	4
ENME 4541	Advanced Mechanics of Materials	4
ENME 4630	Viscous Flow	4
ENME 4670	Advanced Computational Fluid Dynamics	4
ENME 4671	Convective Heat Transfer	4
ENME 4800	Advanced Topics (ME)	4
Bioengineering Core Courses		**4**
ENBI 4500	Biofluids	4
ENBI 4510	Biomechanics	4
ENBI 4520	Introduction to Cardiovascular Engineering	4
ENBI 4800	Adv Topics (Bioengineering)	4
Materials Science Core Courses		
ENGR 4200	Introduction to Nanotechnology	4
ENME 4310	Computational Methods for Mechanics and Materials	4
ENME 4400	Fatigue	4
MTSC 4020	Composite Materials I	4
MTSC 4215	Composite Materials II	4
MTSC 4450	Fracture Mechanics	4
Electrical & Computer Engineering - Any 4XXX level ENEE or ENCE course		
Advanced Math Courses		
ENGR 3621	Advanced Engineering Mathematics	4

ENGR 4300	Advanced Numerical Methods (Advanced Numerical Methods)	4
ENGR 4350	Reliability	4
ENGR 4620	Optimization	4
ENGR 4765	Robot Control	4

Master of Science in Engineering with a Concentration in Engineering Management

Program Structure (management focus)

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. No courses at the 1000- or 2000-level are acceptable.
3. An overall GPA of 3.0 is required for the degree.
4. Any individual grade lower than C- renders the credit unacceptable.
5. 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.
6. Master's degree candidates are expected to complete degree requirements no later than five years after beginning their programs.

Course Requirements:

1. **Core Courses**: a minimum of nine credits (one course from ENME, ENBI, MTSC or ECE Core Course List AND one course from Management Concentration Core Course List) plus required courses.
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 this **non-thesis track** are required to upload to Assessment.du.edu 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 should be selected from ENME, ENBI, MTSC or ECE Core Course List.
4. **Management Electives**: a minimum of 12 credits should be selected from the following provided all prerequisites are met: any 4XXX level ACTG, CMGT, FIN, INFO, INFOR, MGNT, MKTG or REAL courses. These management electives are in addition to the management core credit requirement.
5. **Advanced Math Requirement**:a minimum of three credits from Core Course List or advisor approval.
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 ENGE with a Concentration in Engineering Management **Minimum** Credit Requirements

Requirement	Thesis	Non-Thesis	CM
Core	NA	NA	9
Technical Electives	NA	NA	16
Management Electives	NA	NA	12
Advanced Math	NA	NA	3
Total Credits Required	NA	NA	45

Code	Title	Credits
Required Core Courses		
ENME 4900	Grad Professional Development (Graduate Professional Development)	1
ENME 4950	Graduate Assessment (Graduate Assessment)	0
Concentration in Management Core Courses - see note 4 above		
Mechanical Engineering Core Courses		
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
Bioengineering Core Courses		
ENBI 4500	Biofluids	4
ENBI 4510	Biomechanics	4
ENBI 4520	Introduction to Cardiovascular Engineering (Intro to Cardiovascular Engineering)	4
ENBI 4800	Adv Topics (Bioengineering) (Computational Biomechanics)	4
Materials Science Core Courses		
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
Electrical & Computer Engineering - Any 4XXX level ENEE or ENCE course		
Advanced Math Courses		
ENGR 3620	Advanced Engineering Mathematics - Corporate	4
ENGR 4300	Advanced Numerical Methods (Advanced Numerical Methods)	4
ENGR 4350	Reliability	4
ENGR 4620	Optimization	4

Engineering, Bio (ENBI)

ENBI 4200 Medical Device Development (4 Credits)
Working in a fast-paced competitive biomedical R&D firm is a dramatic change of pace from most college classes. This course will create a realistic industry environment where students take on the role of development engineers to design and manufacture real-world medical devices. This course is intended to provide a working knowledge of the design and development process specifically for medical device applications.

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 4530 Biomechanics of Human Movement (4 Credits)
An introduction to engineering-based analysis of human movement. Topics include: musculoskeletal anatomy, nueromuscular physiology, muscle mechanics, electromyography, sensorimotor integration, anthropometry, kinematics and kinetics. Recommended pre-requisite material: knowledge of MATLAB, ENGR 1572.

ENBI 4600 Biomedical Engineering: Technology, Research, and Design (4 Credits)
Introduction to Biomedical Engineering is an interdisciplinary course that combines engineering principles with biological and medical sciences to advance healthcare in areas such as diagnosis, monitoring, and therapy. The course provides a foundational understanding of biomedical engineering and prepares students for further study or careers in the field.

ENBI 4610 Experimental Design in Biomedical Sciences (4 Credits)
This course offers an in-depth exploration of experimental design principles within the biomedical sciences, emphasizing statistical analysis, measurement techniques, and ethical considerations. It aims to provide students with practical skills necessary for designing, conducting, and analyzing biomedical research.

ENBI 4620 Bioelectronics (4 Credits)
This course introduces the principles and applications of bioelectronics, focusing on the interface between biological systems and electronic devices. It covers the fundamentals of electronic circuits, signal processing, and sensor technology, and their applications in areas like biometric monitoring, neuroprosthetics, and biosensing.

ENBI 4630 Biomaterials (4 Credits)
This course provides an introduction to the field of biomaterials science, focusing on the fundamental principles, properties, and applications of materials used in biomedical engineering and healthcare. Topics covered include the classification of biomaterials, biocompatibility, interactions with biological systems, surface modifications, fabrication techniques, characterization techniques and current applications in tissue engineering, regenerative medicine, drug delivery, and medical devices.

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 4995 Independent Research (1-18 Credits)

Engineering, Mechanical (ENME)

ENME 2410 Materials Science I (4 Credits)
Atomic structure, bonding and crystal structures in solids. Diffusion and crystal defects. Thermodynamics and phase equilibria in one-, two- and three-component systems, binary phase diagrams. Kinetics and phase transformations. Specific microstructure and mechanical properties of metals, glasses, ceramics, polymers and composites. Electrical conduction: energy levels and bands, charge carriers and insulators. Semiconductors of intrinsic and extrinsic types. Laboratory projects/demonstrations. Prerequisites: PHYS 1212 and CHEM 1010 and MATH 1952.

ENME 2421 Materials Science II (3 Credits)
Atomic structure, bonding and crystal structures in solids. Diffusion and crystal defects. Thermodynamics and phase equalibria in one-, two- and three-component systems, binary phase diagrams. Kinetics and phase transformations. Specific microstructure and mechanical properties of metals, glasses, ceramics, polymers and composites. Electrical conduction: energy levels and bands, charge carriers and insulators. Semiconductors of intrinsic and extrinsic types. Laboratory projects/demonstrations. Prerequisites: ENME 2410.

ENME 2510 Statics (4 Credits)
Study of static force systems. Topics include resolution and composition of forces and moments, equilibrium of two-dimensional and three-dimensional force systems, shear and moments in beams, friction, and moments of inertia. Includes a laboratory component where students will engage in hands-on projects that apply loading equilibrium, design of structures, and stress/strain. Prerequisites: MATH 1951 AND PHYS 1211.

ENME 2520 Dynamics I with Lab (4 Credits)
Particles Kinematics, Reference Frames, Coordinate Systems, Newton's Laws, Energy and Momentum, Multiparticle Systems, Collisions, Variable Mass Systems. These topics are addressed through analytical analysis, numerical simulation using Matlab, and experimental data collection. Cross listed with PHYS 2520. Corequisite: MATH 2080; Prerequisite: ENME 2510 AND MATH 2070.

ENME 2530 Dynamics II (3 Credits)
Rotating reference frames, rigid body kinematics, rigid body kinetics, Euler's Laws, inertia, energy and momentum, and three-dimensional motion. Cross listed with PHYS 2530. Prerequisites: ENME 2520.

ENME 2540 System Dynamics (3 Credits)
This course covers modeling, analysis, and control of single and multiple degree-of freedom dynamical systems, including mechanical, electrical, thermal, fluid systems and their combinations (mixed systems). Basic concepts in system theory, such as state variables and stability concepts, will be introduced as well as bond graph notation and approach. Prerequisites: ENME 2530, ENME 2661, ENGR 1572, and ENEE 2012.

ENME 2541 Mechanics of Materials (3 Credits)
Normal and shear stress and strain; elasticity, mechanical properties of materials, principal stresses; torsion, beams, deflection of beams under loads, methods of superposition, failure theory, columns. Prerequisite: ENME 2510.

ENME 2651 Fluid Dynamics I (3 Credits)
Course series provides students with the basic skill levels required to solve fluid-mechanics and heat transfer problems. Topics include hydrostatics, dimensional analysis, incompressible and compressible flows, conduction, convection and radiation. Students explore a variety of solution techniques such as control volume, differential analysis, boundary layer analysis, finite differencing and resistance network analogies. Prerequisite: ENME 2510 and MATH 2070.

ENME 2661 Fluid Dynamics II/Heat Transfer I (3 Credits)
Course series provides students with the basic skills levels required to solve fluid-mechanics and heat transfer problems. Topics include hydrostatics, dimensional analysis, incompressible and compressible flows, conduction, convection and radiation. Students explore a variety of solution techniques such as control volume, differential analysis, boundary layer analysis, finite differencing and resistance network analogies. Prerequisite: ENME 2651.

ENME 2671 Heat Transfer II with Lab (4 Credits)
Course series provides students with the basic skill levels required to solve fluid-mechanics and heat transfer problems. Topics include hydrostatics, dimensional analysis, incompressible and compressible flows, conduction, convection and radiation. Students explore a variety of solution techniques such as control volume, differential analysis, boundary layer analysis, finite differencing and resistance network analogies. Prerequisite: ENME 2661.

ENME 2710 Engineering Thermodynamics I (3 Credits)
Properties of a pure substance. Use of tables of properties. First and second laws of thermodynamics for closed and open systems. Work, heat, power and entropy. Engine, power plant and refrigeration cycles. Gas mixtures, thermodynamic relations and chemical reactions. Prerequisite: PHYS 1212.

ENME 2720 Engineering Thermodynamics II (3 Credits)
Properties of a pure substance. Use of tables of properties. First and second laws of thermodynamics for closed and open systems. Work, heat, power and entropy. Engine, power plant and refrigeration cycles. Gas mixtures, thermodynamic relations and chemical reactions. Prerequisite: ENME 2710.

ENME 2810 Mechanical Engineering Lab I (3 Credits)
Engineering experiments illustrating selected topics in heat transfer, fluid mechanics, solid mechanics, thermodynamics, measurement and control. Use of microcomputers in experimentation and control. This course encourages the development of laboratory experimentation skills, design skills and technical writing skills. Prerequisites: ENME 2540 AND ENME 2671.

ENME 3320 Computer Aided Design and Analysis (4 Credits)
Introduction to the use of computer aided design and analysis with applications to solid and fluid mechanics, heat transfer and vibrations; projects in one or more of the above areas. Emphasis on how to use the software to analyze engineering systems. Prerequisites ENME 2541 and ENME 2651.

ENME 3400 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 4400.

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 discretations and solutions, are presented. Convergence and validity of solutions along with computational efficiency are explored. Students learn to apply these techniques using the latest software packages. 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 Aerospace Engineering: Atmospheric Flight Dynamics (4 Credits)
This course provides and 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 3730 Aerospace Engineering: Space Flight Dynamics (4 Credits)
This course is focused on the aerospace discipline of space environment and orbital mechanics. The topics in this discipline are discussed in detail and provide aid in designing spacecraft/space missions. Some of the topics covered in this course include space environment, satellite orbits, spacecraft configurations, transfer orbits, and elementary space propulsion. 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 3820 Topics Mechanical Engineering (0-5 Credits)
Mechanical engineering topics as announced. May be taken more than once. Prerequisite: vary with offering.

ENME 3991 Independent Study (1-5 Credits)
Topics in mechanical engineering investigated under faculty supervision. May be taken more than once. Students must obtain and complete an Independent Study form from the Office of the Registrar. Prerequisite: permission of instructor.

ENME 3995 Independent Research (1-10 Credits)

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 applicaitons of elasticity. Suggeted 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 approaches. Topics will include: Vector algebraic/differential geometry for 3D translational and rotational kinematic analyses with motion constraints. Formulation of equations of motion for 3D multibody systems using: Newton/Euler equations; Angular momentum principle; and D'Alembert principle (aka road-maps). Some exposure to Euler-Lagrange and Kane's Methods calculations. Symbolic and numerical computational solutions to linear/nonlinear algebraic and differential equations governing the configuration, forces, and motion of systems with multiple degrees of freedom. Recommended prerequisites: MATH 2070.

ENME 4530 Advanced Dynamics (4 Credits)
Formulation of equations of motion for constrained 3D multibody systems with: D'Alembert principle (MG road-maps); power, work, and energy; Lagrange's equations; and Kane's method. Euler parameters/quaternions, specified motion, constraint force/torque calculations, feed- forward control, inequality constraints and/or intermittent contact. Tensors and mass property calculations. Symbolic and numerical computer skills for geometry/kinematic analysis, mass/inertia calculations, forces and motion, and simulation of multi-body dynamic systems. Training for advanced research and professional work. Recommended pre-requisite: ENME 4520.

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 axisymmetic shells, asisymmetric 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 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 4995 Independent Research (1-16 Credits)

ENME 5991 Independent Study (1-10 Credits)

ENME 5995 Independent Research (1-16 Credits)

Engineering (ENGR)

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 3450 Biosensing Technology (4 Credits)
Biosensors are defined as analytical devices incorporating a biological material, a biologically derived material or a biomimic associated with or integrated within a physicochemical transducer or transducing microsystem, which may be optical, electrochemical, thermometric, piezoelectric, magnetic or micromechanical. This course provides instruction in the basic science and engineering concepts required to understand the design and application of biosensors. This module serves as an introduction to some of the biosensors and measurement techniques.

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 2012.

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 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 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 2022, ENGR 3611 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 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 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.

ENGR 4455 Fluorescence and Its Applications in Biomedical Sensors (4 Credits)
The course introduces the principles of fluorescence and its applications in the real world. It covers various topics including fluorophores (dye, fluorescent proteins, quantum dots, etc.), nanomaterials and nanostructures, design of biomedical sensors, point-of-care systems, and wearable devices. Cross listed with ENGR 3455.

ENGR 4501 Graduate Capstone Design I (3 Credits)
This is a project-centered course. This is the first third of a practical class that plans the engineering design project prior to addressing the design in earnest. This requires teamwork to develop the plan that details the schedule, cost, and who is responsible for which portions of the design effort. In this segment, the engineering teams establish the starting point for the design. This class puts theory into practice with the “shredding” of the RFP, defining a strategy for the team, balancing what has to be done with existing constraints, understanding the “true” problem of the customer, capturing the associated risks, and capturing margins required for the start of any design activity.

ENGR 4502 Graduate Capstone Design II (3 Credits)
This is a project-centered course. This is the second third of a practical class that implements the engineering design process (left side of the vee). This requires teamwork to develop the detailed design, which is a continuation of the accepted proposal. In this segment, the engineering teams add the details to a conceptual design. This class puts theory into practice with requirements development, balancing requirements against the constraints, completing a functional decomposition, developing a CONOPs document, developing a physical architecture, developing a functional architecture, and defining the interfaces through an ICD.

ENGR 4503 Graduate Capstone Design III (3 Credits)
This is a project-centered course. This is the third of a practical class that implements the engineering design process (right side of the vee). This requires teamwork to build, checkout, and test the final product. In this segment, the engineering teams build or procure hardware as a step towards the integration of the system. This class puts theory into practice by building components, developing software modules, integrating software with hardware, checkout of the system, and performing tests to verify construction, validate models, and collect data for acceptance by the team prior to demonstrating the operations of the product to the customer. Test data is collected through instrumentation of the final product with a buy-out and certification by the team. Testing may include performance testing and environmental testing as envisioned in the context diagram.

ENGR 4504 Graduate Capstone Design IV (3 Credits)
This is a project-centered course. This is the fourth of a practical class that implements the entire engineering “vee” design process. This requires teamwork to build, checkout, and test the final design product, e.g. hypothetical missile. In this segment, the engineering teams fine-tune the design process which may address advanced topics such as fault management and resilience. This class puts theory into practice by building components, developing software modules, integrating software with hardware, checkout of the system, and performing tests to verify construction, validate models, and collect data for acceptance by the team prior to demonstrating the operations of the product to the customer. It may also include addressing the beginning of the program through early management and pre-phase A activities. Test data is collected through instrumentation of the final product with a buy-in and certification by the team. Testing may include performance testing, functional testing, and environmental testing as envisioned in the system process.

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 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 3530 or ENGR 4530 or permission of instructor.

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 3530 or ENGR 4530.

ENGR 4620 Optimization (4 Credits)
The development and application of various optimization techniques will be explored with engineering examples. Topics include: analytical and numerical methods, linear and non-linear programming techniques for unconstrained and constrained problems, and advanced optimization techniques, e.g. global optimization. Optimization methods will be developed and evaluated in code and used in a real-world application project.

ENGR 4622 Advanced Optimization (4 Credits)
Optimization is an indispensable tool for many fields of science and engineering and is one of the pillars of data science and machine learning. This course introduces optimization methods that are suitable for large-scale problems arising in data science, machine learning, and other engineering applications. We will discuss the development, computation, and convergence aspects for algorithms including gradient methods, accelerated methods, quasi-Newton methods, stochastic optimization, variance reduction, online optimization, as well as distributed optimization. We will also exploit the efficacy of these methods in concrete data science problems, including learning low-dimensional models, deep learning, and (possible) reinforcement learning. This course together with ENGR 4620 Optimization will provide in-depth introductions to optimization.

ENGR 4680 Fault Diagnosis & Prognostics for System Design (4 Credits)
Reliability engineering is a sub-discipline of systems engineering that emphasizes dependability in the lifecycle management of a product. Reliability, describes the ability of a system or component to function under stated conditions for a specified period of time. Reliability is closely related to availability, which is typically described as the ability of a component or system to function at a specified moment or interval of time. Normally, quality focuses on the prevention of defects during the warranty phase whereas reliability looks at preventing failures during the useful lifetime of the product or system from commissioning to decommissioning. Diagnosis is used, with variations in the use of logic, analytics, and experience, to determine "cause and effect". In systems engineering, it is typically used to determine the causes of symptoms, mitigations, and solutions. Prognostics is an engineering discipline focused on predicting the time at which a system or a component will no longer perform its intended function. This lack of performance is most often a failure beyond which the system can no longer be used to meet desired performance. The predicted time then becomes the remaining useful life (RUL), which is an important concept in decision making for contingency mitigation. Success in this course requires knowledge of probability theory and statistics, and familiarity with MATLAB/Simulink.

ENGR 4723 Digital Control (4 Credits)
The course focuses on modeling, analysis, and design of digital control systems. Topics include: z-Transform and difference equations; sampling and aliasing; Zero-Order Hold (ZOH); A/D and D/A conversions; pulse transfer function representation; time and frequency domain representations; input/output analysis; analysis of sample data systems; stability; design of discrete-time controllers; introduction to state-space representation. Cross listed with ENGR 3723. Prerequisites: ENGR 3721 and ENGR 3722.

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: ENGR 3611 or ENEE 3111 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 3611, ENGR 3721, ENGR 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). Prerequisite: 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 (Language multipliers, convexity, Kuhn-Tucker theorem); Pontryagin's maximum principle (constraints, Hamilitonians, 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 4765 Robot Control (4 Credits)
The course focuses on different techniques, methods, and theories for control of robots. The topics covered include: introduction to nonlinear control theory, review of independent joint control, nonlinear and multivariable robot control, feedback linearization control of robots, control of underactuated robots, control of nonholonomic and mobile robots. force and impedance control, and vision-based control. Pre-requisite or co-requisite: ENGR 3730 or ENGR 4730, or equivalent is recommended.

ENGR 4790 Systems Engineering Requirements (4 Credits)
The course covers fundamentals of design and requirements analysis of complex systems to meet overall mission requirements. It spans the whole requirements engineering phase that includes requirements analysis, decomposition, derivation, allocation, verification and validation planning. Students acquire expertise in creating UML and SYML case diagrams and in defining and implementing verification and validation plans. Requirement management methods and tools, associated vernacular, and requirements configuration control are also covered. Prerequisites: ENMT 4100, or permission by the Instructor.

ENGR 4810 Advanced Topics (ENGR) (1-5 Credits)

ENGR 4910 Conceptual Design (4 Credits)
Conceptual design is the part of the design process where—by identifying the essential problems through abstraction, establishing function structures, searching for appropriate working principles and combining these into a working structure— the basic solution path is laid down through the elaboration of a solution principle. Conceptual design specifies the principle solution. Concept design rarely starts at the same point; you might have an existing design that needs iterating or the requirement to create a conceptualized form. Problem solving consists of using generic or ad hoc methods in an orderly manner to find solutions to problems. George Polya (mathematician) presented two important decision-making principles, understanding the problem and devising a plan. To understand what is new, students are asked to look at intellectual property, a category of property that includes intangible creations of the human intellect. There are many types of intellectual property such as patents, and some countries recognize more than others. Designers assess the many different directions a design could take at this stage will allow you to identify what you like and don't like from each one. The preferred concept will then be further developed using engineering drawings, schematics and possibly 3D models which will show how the design will look and operate.

ENGR 4920 Aerospace Missions (4 Credits)
The Design "Problem" in Advanced Aerospace Systems describes the problems in the conceptual design of various types of aircraft, spacecraft, and complex vehicles. It covers the following topics: design of orbital spacecraft, design for Moon missions (such as landers), design for Mars missions (including rovers), design of an unmanned drone for surveillance (high-altitudes), CubeSats (having large constellations), and rockets and missiles (including hypersonic). Problem statements are concise descriptions of design problems. Design teams use them to define the current and ideal states, to freely find user-centered solutions. This class stands as a reference of interest to engineers and scientists working in aerospace engineering and related topics.

ENGR 4940 Mission Operation Controls (4 Credits)
Space operations is based at a centralized control center, a facility used for command & control (C2), and related communication equipment (antennas, etc.). The human operators conduct the day-to-day operations for controlling the spacecraft. They control the spacecraft and its payloads, and carries out all activities related to mission planning and scheduling. For example, normal orbital operations are interrupted every six months to conduct orbital maneuvers. Launch operations begin with spacecraft integration and checked-out for launch. Once safely placed in orbit, command and control goes back and forth between the ground control station and the spacecraft or satellite. A key aspect of spacecraft operations is the transferring of data from the onboard instruments collected by its payload to the ground, eventually disseminating the data to concerned users and analysts through a ground data network. This requires an on-orbit communication architecture.

ENGR 4991 Independent Study (1-5 Credits)

ENGR 4995 Independent Research (1-16 Credits)

ENGR 5991 Independent Study (0-10 Credits)

ENGR 5995 Independent Research (1-16 Credits)

Materials Science (MTSC)

MTSC 3020 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 4020. Prerequisites: ENME 2410 and ENME 2541.

MTSC 3800 Topics in Materials Science (1-5 Credits)
Various topics in materials science as announced. May be taken more than once. Prerequisite: varies with each topic.

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 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 4991 Independent Study (1-10 Credits)

MTSC 4995 Independent Research (1-16 Credits)

MTSC 5995 Independent Research (1-16 Credits)

Engineering Courses

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 3450 Biosensing Technology (4 Credits)
Biosensors are defined as analytical devices incorporating a biological material, a biologically derived material or a biomimic associated with or integrated within a physicochemical transducer or transducing microsystem, which may be optical, electrochemical, thermometric, piezoelectric, magnetic or micromechanical. This course provides instruction in the basic science and engineering concepts required to understand the design and application of biosensors. This module serves as an introduction to some of the biosensors and measurement techniques.

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 2012.

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 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 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 2022, ENGR 3611 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 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 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.

ENGR 4455 Fluorescence and Its Applications in Biomedical Sensors (4 Credits)
The course introduces the principles of fluorescence and its applications in the real world. It covers various topics including fluorophores (dye, fluorescent proteins, quantum dots, etc.), nanomaterials and nanostructures, design of biomedical sensors, point-of-care systems, and wearable devices. Cross listed with ENGR 3455.

ENGR 4501 Graduate Capstone Design I (3 Credits)
This is a project-centered course. This is the first third of a practical class that plans the engineering design project prior to addressing the design in earnest. This requires teamwork to develop the plan that details the schedule, cost, and who is responsible for which portions of the design effort. In this segment, the engineering teams establish the starting point for the design. This class puts theory into practice with the “shredding” of the RFP, defining a strategy for the team, balancing what has to be done with existing constraints, understanding the “true” problem of the customer, capturing the associated risks, and capturing margins required for the start of any design activity.

ENGR 4502 Graduate Capstone Design II (3 Credits)
This is a project-centered course. This is the second third of a practical class that implements the engineering design process (left side of the vee). This requires teamwork to develop the detailed design, which is a continuation of the accepted proposal. In this segment, the engineering teams add the details to a conceptual design. This class puts theory into practice with requirements development, balancing requirements against the constraints, completing a functional decomposition, developing a CONOPs document, developing a physical architecture, developing a functional architecture, and defining the interfaces through an ICD.

ENGR 4503 Graduate Capstone Design III (3 Credits)
This is a project-centered course. This is the third of a practical class that implements the engineering design process (right side of the vee). This requires teamwork to build, checkout, and test the final product. In this segment, the engineering teams build or procure hardware as a step towards the integration of the system. This class puts theory into practice by building components, developing software modules, integrating software with hardware, checkout of the system, and performing tests to verify construction, validate models, and collect data for acceptance by the team prior to demonstrating the operations of the product to the customer. Test data is collected through instrumentation of the final product with a buy-out and certification by the team. Testing may include performance testing and environmental testing as envisioned in the context diagram.

ENGR 4504 Graduate Capstone Design IV (3 Credits)
This is a project-centered course. This is the fourth of a practical class that implements the entire engineering “vee” design process. This requires teamwork to build, checkout, and test the final design product, e.g. hypothetical missile. In this segment, the engineering teams fine-tune the design process which may address advanced topics such as fault management and resilience. This class puts theory into practice by building components, developing software modules, integrating software with hardware, checkout of the system, and performing tests to verify construction, validate models, and collect data for acceptance by the team prior to demonstrating the operations of the product to the customer. It may also include addressing the beginning of the program through early management and pre-phase A activities. Test data is collected through instrumentation of the final product with a buy-in and certification by the team. Testing may include performance testing, functional testing, and environmental testing as envisioned in the system process.

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 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 3530 or ENGR 4530 or permission of instructor.

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 3530 or ENGR 4530.

ENGR 4620 Optimization (4 Credits)
The development and application of various optimization techniques will be explored with engineering examples. Topics include: analytical and numerical methods, linear and non-linear programming techniques for unconstrained and constrained problems, and advanced optimization techniques, e.g. global optimization. Optimization methods will be developed and evaluated in code and used in a real-world application project.

ENGR 4622 Advanced Optimization (4 Credits)
Optimization is an indispensable tool for many fields of science and engineering and is one of the pillars of data science and machine learning. This course introduces optimization methods that are suitable for large-scale problems arising in data science, machine learning, and other engineering applications. We will discuss the development, computation, and convergence aspects for algorithms including gradient methods, accelerated methods, quasi-Newton methods, stochastic optimization, variance reduction, online optimization, as well as distributed optimization. We will also exploit the efficacy of these methods in concrete data science problems, including learning low-dimensional models, deep learning, and (possible) reinforcement learning. This course together with ENGR 4620 Optimization will provide in-depth introductions to optimization.

ENGR 4680 Fault Diagnosis & Prognostics for System Design (4 Credits)
Reliability engineering is a sub-discipline of systems engineering that emphasizes dependability in the lifecycle management of a product. Reliability, describes the ability of a system or component to function under stated conditions for a specified period of time. Reliability is closely related to availability, which is typically described as the ability of a component or system to function at a specified moment or interval of time. Normally, quality focuses on the prevention of defects during the warranty phase whereas reliability looks at preventing failures during the useful lifetime of the product or system from commissioning to decommissioning. Diagnosis is used, with variations in the use of logic, analytics, and experience, to determine "cause and effect". In systems engineering, it is typically used to determine the causes of symptoms, mitigations, and solutions. Prognostics is an engineering discipline focused on predicting the time at which a system or a component will no longer perform its intended function. This lack of performance is most often a failure beyond which the system can no longer be used to meet desired performance. The predicted time then becomes the remaining useful life (RUL), which is an important concept in decision making for contingency mitigation. Success in this course requires knowledge of probability theory and statistics, and familiarity with MATLAB/Simulink.

ENGR 4723 Digital Control (4 Credits)
The course focuses on modeling, analysis, and design of digital control systems. Topics include: z-Transform and difference equations; sampling and aliasing; Zero-Order Hold (ZOH); A/D and D/A conversions; pulse transfer function representation; time and frequency domain representations; input/output analysis; analysis of sample data systems; stability; design of discrete-time controllers; introduction to state-space representation. Cross listed with ENGR 3723. Prerequisites: ENGR 3721 and ENGR 3722.

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: ENGR 3611 or ENEE 3111 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 3611, ENGR 3721, ENGR 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). Prerequisite: 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 (Language 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 4765 Robot Control (4 Credits)
The course focuses on different techniques, methods, and theories for control of robots. The topics covered include: introduction to nonlinear control theory, review of independent joint control, nonlinear and multivariable robot control, feedback linearization control of robots, control of underactuated robots, control of nonholonomic and mobile robots. force and impedance control, and vision-based control. Pre-requisite or co-requisite: ENGR 3730 or ENGR 4730, or equivalent is recommended.

ENGR 4790 Systems Engineering Requirements (4 Credits)
The course covers fundamentals of design and requirements analysis of complex systems to meet overall mission requirements. It spans the whole requirements engineering phase that includes requirements analysis, decomposition, derivation, allocation, verification and validation planning. Students acquire expertise in creating UML and SYML case diagrams and in defining and implementing verification and validation plans. Requirement management methods and tools, associated vernacular, and requirements configuration control are also covered. Prerequisites: ENMT 4100, or permission by the Instructor.

ENGR 4810 Advanced Topics (ENGR) (1-5 Credits)

ENGR 4910 Conceptual Design (4 Credits)
Conceptual design is the part of the design process where—by identifying the essential problems through abstraction, establishing function structures, searching for appropriate working principles and combining these into a working structure— the basic solution path is laid down through the elaboration of a solution principle. Conceptual design specifies the principle solution. Concept design rarely starts at the same point; you might have an existing design that needs iterating or the requirement to create a conceptualized form. Problem solving consists of using generic or ad hoc methods in an orderly manner to find solutions to problems. George Polya (mathematician) presented two important decision-making principles, understanding the problem and devising a plan. To understand what is new, students are asked to look at intellectual property, a category of property that includes intangible creations of the human intellect. There are many types of intellectual property such as patents, and some countries recognize more than others. Designers assess the many different directions a design could take at this stage will allow you to identify what you like and don’t like from each one. The preferred concept will then be further developed using engineering drawings, schematics and possibly 3D models which will show how the design will look and operate.

ENGR 4920 Aerospace Missions (4 Credits)
The Design “Problem” in Advanced Aerospace Systems describes the problems in the conceptual design of various types of aircraft, spacecraft, and complex vehicles. It covers the following topics: design of orbital spacecraft, design for Moon missions (such as landers), design for Mars missions (including rovers), design of an unmanned drone for surveillance (high-altitudes), CubeSats (having large constellations), and rockets and missiles (including hypersonic). Problem statements are concise descriptions of design problems. Design teams use them to define the current and ideal states, to freely find user-centered solutions. This class stands as a reference of interest to engineers and scientists working in aerospace engineering and related topics.

ENGR 4940 Mission Operation Controls (4 Credits)
Space operations is based at a centralized control center, a facility used for command & control (C2), and related communication equipment (antennas, etc.). The human operators conduct the day-to-day operations for controlling the spacecraft. They control the spacecraft and its payloads, and carries out all activities related to mission planning and scheduling. For example, normal orbital operations are interrupted every six months to conduct orbital maneuvers. Launch operations begin with spacecraft integration and checked-out for launch. Once safely placed in orbit, command and control goes back and forth between the ground control station and the spacecraft or satellite. A key aspect of spacecraft operations is the transferring of data from the onboard instruments collected by its payload to the ground, eventually disseminating the data to concerned users and analysts through a ground data network. This requires an on-orbit communication architecture.

ENGR 4991 Independent Study (1-5 Credits)

ENGR 4995 Independent Research (1-16 Credits)

ENGR 5991 Independent Study (0-10 Credits)

ENGR 5995 Independent Research (1-16 Credits)

Engineering, Bio Courses

ENBI 4200 Medical Device Development (4 Credits)
Working in a fast-paced competitive biomedical R&D firm is a dramatic change of pace from most college classes. This course will create a realistic industry environment where students take on the role of development engineers to design and manufacture real-world medical devices. This course is intended to provide a working knowledge of the design and development process specifically for medical device applications.

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 4530 Biomechanics of Human Movement (4 Credits)
An introduction to engineering-based analysis of human movement. Topics include: musculoskeletal anatomy, nueromuscular physiology, muscle mechanics, electromyography, sensorimotor integration, anthropometry, kinematics and kinetics. Recommended pre-requisite material: knowledge of MATLAB, ENGR 1572.

ENBI 4600 Biomedical Engineering: Technology, Research, and Design (4 Credits)
Introduction to Biomedical Engineering is an interdisciplinary course that combines engineering principles with biological and medical sciences to advance healthcare in areas such as diagnosis, monitoring, and therapy. The course provides a foundational understanding of biomedical engineering and prepares students for further study or careers in the field.

ENBI 4610 Experimental Design in Biomedical Sciences (4 Credits)
This course offers an in-depth exploration of experimental design principles within the biomedical sciences, emphasizing statistical analysis, measurement techniques, and ethical considerations. It aims to provide students with practical skills necessary for designing, conducting, and analyzing biomedical research.

ENBI 4620 Bioelectronics (4 Credits)
This course introduces the principles and applications of bioelectronics, focusing on the interface between biological systems and electronic devices. It covers the fundamentals of electronic circuits, signal processing, and sensor technology, and their applications in areas like biometric monitoring, neuroprosthetics, and biosensing.

ENBI 4630 Biomaterials (4 Credits)
This course provides an introduction to the field of biomaterials science, focusing on the fundamental principles, properties, and applications of materials used in biomedical engineering and healthcare. Topics covered include the classification of biomaterials, biocompatibility, interactions with biological systems, surface modifications, fabrication techniques, characterization techniques and current applications in tissue engineering, regenerative medicine, drug delivery, and medical devices.

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 4995 Independent Research (1-18 Credits)

Engineering, Mechanical Courses

ENME 3320 Computer Aided Design and Analysis (4 Credits)
Introduction to the use of computer aided design and analysis with applications to solid and fluid mechanics, heat transfer and vibrations; projects in one or more of the above areas. Emphasis on how to use the software to analyze engineering systems. Prerequisites ENME 2541 and ENME 2651.

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 discretations and solutions, are presented. Convergence and validity of solutions along with computational efficiency are explored. Students learn to apply these techniques using the latest software packages. 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 Aerospace Engineering: Atmospheric Flight Dynamics (4 Credits)
This course provides and 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 3730 Aerospace Engineering: Space Flight Dynamics (4 Credits)
This course is focused on the aerospace discipline of space environment and orbital mechanics. The topics in this discipline are discussed in detail and provide aid in designing spacecraft/space missions. Some of the topics covered in this course include space environment, satellite orbits, spacecraft configurations, transfer orbits, and elementary space propulsion. 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 applicaitons of elasticity. Suggeted 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 approaches. Topics will include: Vector algebraic/differential geometry for 3D translational and rotational kinematic analyses with motion constraints. Formulation of equations of motion for 3D multibody systems using: Newton/Euler equations; Angular momentum principle; and D'Alembert principle (aka road-maps). Some exposure to Euler-Lagrange and Kane's Methods calculations. Symbolic and numerical computational solutions to linear/nonlinear algebraic and differential equations governing the configuration, forces, and motion of systems with multiple degrees of freedom. Recommended prerequisites: MATH 2070.

ENME 4530 Advanced Dynamics (4 Credits)
Formulation of equations of motion for constrained 3D multibody systems with: D'Alembert principle (MG road-maps); power, work, and energy; Lagrange's equations; and Kane's method. Euler parameters/quaternions, specified motion, constraint force/torque calculations, feed- forward control, inequality constraints and/or intermittent contact. Tensors and mass property calculations. Symbolic and numerical computer skills for geometry/kinematic analysis, mass/inertia calculations, forces and motion, and simulation of multi-body dynamic systems. Training for advanced research and professional work. Recommended pre-requisite: ENME 4520.

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 axisymmetic shells, asisymmetric 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 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 4995 Independent Research (1-16 Credits)

ENME 5991 Independent Study (1-10 Credits)

ENME 5995 Independent Research (1-16 Credits)

Materials Science Courses

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 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 4991 Independent Study (1-10 Credits)

MTSC 4995 Independent Research (1-16 Credits)

MTSC 5995 Independent Research (1-16 Credits)