Twin Cities Campus
Aerospace Engineering and Mechanics M.S.

Aerospace Engineering & Mechanics
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Director of Graduate Studies, Department of Aerospace Engineering and Mechanics, University of Minnesota, 107 Akerman Hall, 110 Union Street S.E., Minneapolis, MN 55455 (612-625-8000; fax: 612-626-1558)
Email: aem-dgs@umn.edu
Website: http://www.aem.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The Department of Aerospace Engineering and Mechanics offers MS and PhD degrees. The graduate programs emphasize engineering sciences that are basic to fluid mechanics, aerospace systems, and solid mechanics. Theoretical, analytical, experimental, and computational aspects of these fields are covered by the courses and research opportunities offered by the department.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.20.

A four-year BS degree in an engineering, basic science, or mathematics program is required.

Other requirements to be completed before admission:
Admission depends primarily on the applicant's undergraduate record and letters of recommendation.

Special Application Requirements:
GRE scores are not required but are strongly recommended for students applying for graduate fellowships. In all cases, these test scores are taken into account if provided. Students are admitted fall semester only. Only under unusual circumstances are students allowed to begin their studies at another time during the academic year.

The application deadline is December 15. Additional information is available at aem.umn.edu/teaching/graduate/

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
Program Requirements

Plan A: Plan A requires 14 major credits, 6 credits outside the major, and 10 thesis credits. The final exam is oral.

Plan B: Plan B requires 14 to 24 major credits and 6 to 16 credits outside the major. The final exam is oral.

Plan C: Plan C requires 14 to 24 major credits and 6 to 16 credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 2.80 is required for students to remain in good standing.

This program emphasizes coursework in engineering sciences that are basic to this field: fluid mechanics, aerospace systems, and solid mechanics. Options include coursework in aerodynamics and aerospace systems, dynamical systems, material properties, and fluid and solid behavior.

The MS in aerospace engineering and mechanics requires 30 credits and is offered under Plan A (thesis), Plan B (project), and Plan C (coursework). All plans require a minimum of 14 major credits, of which 12 must be at the 5xxx or 8xxx level, and a minimum of 6 credits outside the major. In addition, Plan A requires 10 thesis credits, and Plan B requires 3 project credits (which may be counted toward the 14 major credits). The remaining course credits may be taken in the major field or in any related field. Two semesters of seminar (AEM 8000) attendance are required, but only one credit may be used towards the course credit requirements. No more than 8 credits of 4xxx courses and no more than 8 credits (6 for Plan A) taken as S/N are allowed.

Required Courses
Take one 2-course sequence in fluids, solids or dynamics

Fluids
AEM 8201 - Fluid Mechanics I (3.0 cr)
AEM 8202 - Fluid Mechanics II (3.0 cr)

Solids
AEM 5501 - Continuum Mechanics (3.0 cr)
AEM 5503 - Theory of Elasticity (3.0 cr)

Dynamics
AEM 5401 - Intermediate Dynamics (3.0 cr)
AEM 8411 - Advanced Dynamics (3.0 cr)

Additional Major Credits
Take an additional 8 credits in AEM. The following sequences in controls or computational fluid mechanics may be used, or any other AEM courses chosen in consultation with advisor.

Controls
AEM 5321 - Modern Feedback Control (3.0 cr)
AEM 5451 - Optimal Estimation (3.0 cr)
AEM 8421 - Robust Multivariable Control Design (3.0 cr)

Computational Fluid Dynamics
AEM 5253 - Computational Fluid Mechanics (3.0 cr)
AEM 8253 - Computational Methods in Fluid Mechanics (3.0 cr)

Seminar
1 credit of AEM 8000 may be used towards program credit requirements.
AEM 8000 - Seminar: Aerospace Engineering and Mechanics (1.0 cr)

Minor or Related Field
For all plans, take a minimum of 6 credits in a minor or in related fields outside AEM

Plan A
Take a minimum of 10 thesis credits
AEM 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Plan B
Take 3 credits of AEM 8880 and complete a final project.
AEM 8880 - Plan B Project (1.0 - 3.0 cr)
Twin Cities Campus
Aerospace Engineering and Mechanics Minor
Aerospace Engineering & Mechanics
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Director of Graduate Studies, Department of Aerospace Engineering and Mechanics, University of Minnesota, 107 Akerman Hall, 110 Union Street S.E., Minneapolis, MN 55455 (612-625-8000; fax: 612-626-1558)
Email: aem-dgs@umn.edu
Website: http://www.aem.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The Department of Aerospace Engineering and Mechanics offers MS and PhD degrees in aerospace engineering and mechanics. The graduate programs emphasize engineering sciences that are basic to fluid mechanics, aerospace systems, and solid mechanics. Theoretical, analytical, experimental, and computational aspects of these fields are covered by the courses and research opportunities offered by the department.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
A four-year BS degree in an engineering, basic science, or mathematics program is required. Admission depends primarily on the applicant's undergraduate record and letters of recommendation.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

The minor in Aerospace Engineering and Mechanics requires 6 credits in AEM courses for the master's minor and 12 credits in AEM courses for the doctoral minor.

One course sequence in one of the following research areas must be included: fluids, solids, dynamics, controls, or computational fluid dynamics.

Courses cross listed with AEM courses must be registered for under the AEM course designation to be counted towards a minor.

Required Courses
One course sequence must be included for either a master's minor or a doctoral minor.

Fluids
AEM 8201 - Fluid Mechanics I (3.0 cr)
AEM 8202 - Fluid Mechanics II (3.0 cr)

Solids
AEM 5501 - Continuum Mechanics (3.0 cr)
AEM 5503 - Theory of Elasticity (3.0 cr)

Dynamics
AEM 5401 - Intermediate Dynamics (3.0 cr)

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
AEM 8411 - Advanced Dynamics (3.0 cr)

Controls
AEM 5321 - Modern Feedback Control (3.0 cr)
AEM 5451 - Optimal Estimation (3.0 cr)
AEM 8421 - Robust Multivariable Control Design (3.0 cr)

Computational Fluid Dynamics
AEM 5253 - Computational Fluid Mechanics (3.0 cr)
AEM 8253 - Computational Methods in Fluid Mechanics (3.0 cr)

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Master's Minor
At least 6 credits in Aerospace Engineering and Mechanics are required, including one sequence of two 5xxx or 8xxx courses.

Doctoral Minor
At least 12 credits in Aerospace Engineering and Mechanics are required, including one sequence of two 5xxx or 8xxx courses.
Twin Cities Campus
Aerospace Engineering and Mechanics Ph.D.
Aerospace Engineering & Mechanics
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Director of Graduate Studies, Department of Aerospace Engineering and Mechanics, University of Minnesota, 107 Akerman Hall, 110 Union Street S.E., Minneapolis, MN 55455 (612-625-8000; fax: 612-626-1558)
Email: aem-dgs@umn.edu
Website: http://www.aem.umn.edu

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 66
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The Department of Aerospace Engineering and Mechanics offers a PhD degree in aerospace engineering and mechanics. The PhD program emphasizes engineering sciences that are basic to fluid mechanics, aerospace systems, and solid mechanics. Theoretical, analytical, experimental, and computational aspects of these fields are covered by the courses and research opportunities offered by the department.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.20.

A four-year BS degree in an engineering, basic science, or mathematics program is required.

Other requirements to be completed before admission:
Admission depends primarily on the applicant's undergraduate record, personal statement, and letters of recommendation.

Special Application Requirements:
GRE scores are not required but are strongly recommended for students applying for graduate fellowships. In all cases, these test scores are taken into account if provided. Students are admitted fall semester only. Only under unusual circumstances are students allowed to begin their studies at another time during the academic year.

The application deadline is December 15. Additional information is available at aem.umn.edu/teaching/graduate/.

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.
Program Requirements
12 to 30 credits are required in the major.
12 to 30 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.0 is required for students to remain in good standing.

The PhD program emphasizes coursework and research in engineering sciences that are basic to this field. Options include coursework and research in aerodynamics and aerospace systems, dynamical systems, material properties, and fluid and solid behavior.

The PhD requires about two years of coursework, but the heart of the program is the student's thesis research. The first year of the PhD program is similar to the master's program and most PhD students receive the master's degree. The second year is devoted to more advanced courses and beginning research. Subsequent years include some coursework with increased focus on research. The time required to complete a research project varies, but most students finish the PhD within five years after the bachelor's degree.

The program must include a minimum of 42 credits of approved courses; of these, a minimum of 12 credits must be in AEM courses at the 5xxx or 8xxx level and a minimum of 12 credits outside the major are required. Four semesters of seminar attendance are required (AEM 8000), but only one credit may be used towards the course credit requirements. The remaining 18 course credits may be taken in the major or in any supporting field. No more than 8 credits of 4xxx level courses and no more than 13 credits taken as S/N are allowed.

Required Courses
Take one 2-course sequence in fluids, solids or dynamics

Fluids
AEM 8201 - Fluid Mechanics I (3.0 cr)
AEM 8202 - Fluid Mechanics II (3.0 cr)

Solids
AEM 5501 - Continuum Mechanics (3.0 cr)
AEM 5503 - Theory of Elasticity (3.0 cr)

Dynamics
AEM 5401 - Intermediate Dynamics (3.0 cr)
AEM 8411 - Advanced Dynamics (3.0 cr)

Additional Major Credits
Take an additional 6 credits in AEM at the 5xxx or 8xxx level. The following sequences in controls or computational fluid mechanics may be used, or any other AEM courses chosen in consultation with adviser.

Controls
AEM 5321 - Modern Feedback Control (3.0 cr)
AEM 5451 - Optimal Estimation (3.0 cr)
AEM 8421 - Robust Multivariable Control Design (3.0 cr)

Computational Fluid Dynamics
AEM 5253 - Computational Fluid Mechanics (3.0 cr)
AEM 8253 - Computational Methods in Fluid Mechanics (3.0 cr)

Minor or Supporting Program
Take 12 credits in a minor or supporting program outside AEM

Seminar
1 credit of AEM 8000 may be used towards program credit requirements.
AEM 8000 - Seminar: Aerospace Engineering and Mechanics (1.0 cr)

Thesis Credits
Take 24 credits after passing preliminary oral exam
AEM 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)
Twin Cities Campus
Astrophysics M.S.
Astrophysics, Minnesota Institute for
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Minnesota Institute for Astrophysics, 116 Church Street S.E., Minneapolis, MN 55455 (612-624-4811; fax: 612-626-2029)
Email: MIfA-gradreq@umn.edu
Website: http://www.astro.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Astrophysics is the study of the universe and its constituent parts. The department conducts research in observational, theoretical, and computational astrophysics, as well as instrument development. The main research areas include minor planetary bodies, solar system properties, dynamics of normal and active galaxies, stellar evolution, interaction of stars with their environments, the interstellar medium, astrophysical magnetohydrodynamics, and galactic and cosmological structure. Observational research includes activities that cover X-ray, ultraviolet, optical, infrared, and radio wavelengths. Extensive research programs in space physics, nucleosynthesis, and the elementary particle-cosmology interface are also carried out in interdisciplinary connections with the graduate program in physics.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.50.

An undergraduate degree in astronomy or physics or the equivalent is required. Contact the Graduate Studies Committee for exceptions.

Other requirements to be completed before admission:
A statement of career goals, scores from the GRE General (Aptitude) Test and Subject (Advanced) Test in physics, and three letters of recommendation are required. Applications are due by January 1 to be considered for fellowships and by January 15 for teaching and research assistantships. Students are admitted fall semester only. Additional application information is available at www.astro.umn.edu/grad/apply/

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
- Paper Based - Total Score: 550
- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the
Program Requirements

Plan A: Plan A requires 14 major credits, 6 credits outside the major, and 10 thesis credits. The final exam is oral.

Plan B: Plan B requires 14 to 24 major credits and 6 to 16 credits outside the major. The final exam is oral.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

The master's degree requires a minimum of 30 credits and is offered under Plan A (thesis) or Plan B (project). Completion of the degree normally takes two years.

Required Coursework

All students are required to take the following course

PHYS 5011 - Classical Physics I (4.0 cr)

Plan A

Plan A requires 14 credits in astrophysics, 6 credits in a minor or in related fields outside AST, and 10 thesis credits

AST 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Plan B

Plan B requires 14 credits in astrophysics and 6 credits in a minor or in related fields outside of AST. The remaining 10 credits may be taken in the major field or any supporting field. The Plan B also requires the completion of 1-3 papers written in connection with three courses taken in the program.
Twin Cities Campus

Astrophysics Minor
Astrophysics, Minnesota Institute for
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Minnesota Institute for Astrophysics, 116 Church Street S.E., Minneapolis, MN 55455 (612-624-4811; fax: 612-626-2029)
Email: MIfA+gradreq@umn.edu
Website: http://www.astro.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 8
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Astrophysics is the study of the universe and its constituent parts. The department conducts research in observational, theoretical, and computational astrophysics, as well as instrument development. The main research areas include minor planetary bodies, solar system properties, dynamics of normal and active galaxies, stellar evolution, interaction of stars with their environments, the interstellar medium, astrophysical magnetohydrodynamics, and galactic and cosmological structure. Observational research includes activities that cover X-ray, ultraviolet, optical, infrared, and radio wavelengths. Extensive research programs in space physics, nucleosynthesis, and the elementary particle-cosmology interface are also carried out in interdisciplinary connections with the graduate program in physics.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.50.

Other requirements to be completed before admission:
Current enrollment in a related University graduate program.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

AST courses at the 5xxx-level or higher may be used for the minor with the exception of AST 8990 and 8200.

Courses at the 4xxx-level may be used with approval from the Director of Graduate Studies.

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Masters

Doctoral
Twin Cities Campus

Astrophysics Ph.D.

Astrophysics, Minnesota Institute for

College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Minnesota Institute for Astrophysics, 116 Church Street S.E., Minneapolis, MN 55455 (612-624-4811; fax: 612-626-2029)
Email: MIfA-gradreq@umn.edu
Website: http://www.astro.umn.edu

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 64
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Astrophysics is the study of the universe and its constituent parts. The department conducts research in observational, theoretical, and computational astrophysics, as well as instrument development. The main research areas include minor planetary bodies, solar system properties, dynamics of normal and active galaxies, stellar evolution, interaction of stars with their environments, the interstellar medium, astrophysical magnetohydrodynamics, and galactic and cosmological structure. Observational research includes activities that cover X-ray, ultraviolet, optical, infrared, and radio wavelengths. Extensive research programs in space physics, nucleosynthesis, and the elementary particle-cosmology interface are also carried out in interdisciplinary connections with the graduate program in physics.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.50.

Undergraduate astronomy, physics or equivalent degree required.

Other requirements to be completed before admission:
Coursework in analytical mechanics, electrodynamics, quantum mechanics, thermodynamics, and statistical physics.

Special Application Requirements:
A statement of career goals, scores from the GRE General (Aptitude) Test and Subject (Advanced) Test in physics, and three letters of recommendation are required. Applications are due by January 1 to be considered for fellowships and by January 15 for teaching and research assistantships. Students are admitted fall semester only. Additional application information is available at www.astro.umn.edu/grad/apply/

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80

The preferred English language test is Test of English as Foreign Language.
Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
28 credits are required in the major.
12 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.0 is required for students to remain in good standing.

The PhD degree requires a minimum of 40 course credits, including 28 credits in the major, and 12 credits in a minor or supporting program; 24 thesis credits are also required.

The graduate written examination, typically held during the week prior to the start of fall semester, must be passed on the second "real" attempt (first-year students are given a free trial). A second-year project must be defended by the end of the fall semester of the third year. The preliminary oral exam must be passed by the end of the third year. Normally, the preliminary oral exam includes a presentation on the second-year project.

Required Courses
The following 2 courses are required for all students. The remaining 20 major credits are chosen in consultation with advisor.
PHYS 5011 - Classical Physics I (4.0 cr)
PHYS 5012 - Classical Physics II (4.0 cr)

Supporting Program
Students must take a minimum of 12 credits in coursework from related fields. Specific courses are chosen in consultation with advisor.

Thesis Credits
Take 24 credits after passing preliminary oral exam.
AST 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)
Biomedical engineering is the application of engineering principles and methods to problems in biology and medicine. The discipline includes the study of fundamental processes in biology and physiology, the study of the diagnosis and treatment of disease and injury, and the design and development of medical devices and techniques. Students take courses in mathematics, biology, biomedical engineering, and areas of science and engineering that are relevant to the degree objectives.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)
• partially online (between 50% to 80% of instruction is online)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.20.

A baccalaureate degree in engineering or in a physical or biological science is required.

Other requirements to be completed before admission:
Applicants with an engineering degree do not need to complete any specific coursework prior to applying. Applicants without an engineering degree must complete (1) math coursework through calculus I, calculus II, linear algebra, and differential equations; and (2) at least 1 year of college-level physics, preferably calculus-based.

There are no minimum GPA, GRE, or English language test score requirements. A GPA of at least 3.2 on a 4.0 scale is preferred, but not required. Applicants with a lower GPA may still apply, but they will have a much lower chance of admission.

Special Application Requirements:
The fall application deadline for M.S. applicants is March 31. Local applicants applying for the program as part-time students may, under certain circumstances, be considered for spring admission. Application instructions are available at http://bme.umn.edu/grad/appinfo.html.

Students applying through the Combined B.Bm.E./M.S. Program (see below, under Program Sub-Plans) should refer to the application instructions and deadline information at http://bme.umn.edu/grad/appcombined.html.

Applicants must submit their test score(s) from the following:
• GRE

International applicants must submit score(s) from one of the following tests:
• TOEFL
• IELTS

The preferred English language test is Test of English as Foreign Language
Key to test abbreviations (GRE, TOEFL, IELTS).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

**Program Requirements**

**Plan A**: Plan A requires 8 to 20 major credits, 0 to 12 credits outside the major, and 10 thesis credits. The final exam is oral.

**Plan B**: Plan B requires 10 to 30 major credits and 0 to 20 credits outside the major. The final exam is oral. A capstone project is required.

**Capstone Project**: The Plan B Project (BMEn 8820, minimum of 2 credits) should entail approximately 50-75 hours of work per credit, performed in collaboration with a faculty advisor. Students must submit a written report of approximately 10 double-spaced pages per credit to the advisor, who will assign a letter grade for BMEn 8820 based on the report. The report must then be defended before the student's committee.

**Plan C**: Plan C requires 8 to 30 major credits and 0 to 22 credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 2.80 is required for students to remain in good standing.

The MS program requires a minimum of 30 total credits in mathematics, biology, biomedical engineering, and relevant areas of science and engineering.

**PLAN A**

- BMEn Core - 6 credits
- BMEn Seminars - 2 credits
- Biology Electives - 6 credits
- Technical Electives - 6 credits
- Thesis - 10 credits

**PLAN B**

- BMEn Core - 6 credits
- BMEn Seminars - 2 credits
- Biology Electives - 6 credits
- Technical Electives - 9 credits
- Free Electives - 5 credits
- Capstone Project - 2 credits

**PLAN C**

- BMEn Core - 6 credits
- BMEn Seminars - 2 credits
- Biology Electives - 6 credits
- Technical Electives - 9 credits
- Free Electives - 7 credits

A single course may NOT be counted simultaneously toward more than one of the requirements listed above.

Math/Statistics (Plans A, B, and C) - Included in the Core/Elective requirements listed above must be a minimum of 3 credits designated as math-/statistics-intensive. These are not additional credits but will overlap with coursework already satisfying the BMEn Core, Technical Elective, and/or Free Elective requirements.

8000 Level (Plans A and B only) - Core/Elective coursework must include at least 3 credits at the 8000 level, from any department (does not need to be BMEn). Credits of seminar, directed research, internship, project, thesis, and/or independent study cannot be used to fulfill this requirement. Plan C students are not required to complete 8000-level coursework.

Approved courses for each category are listed below. All coursework (excluding seminars and internships) must be taken for a letter grade (A-F). A minimum grade of B- is required for coursework to be counted toward degree requirements.
BMEn Core
Take 6 or more credit(s) from the following:
• BMEN 5001 - Advanced Biomaterials (3.0 cr)
• BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
• BMEN 5201 - Advanced Biomechanics (3.0 cr)
• BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
• BMEN 5351 - Cell Engineering (3.0 cr)
• BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
• BMEN 8001 - Polymeric Biomaterials (3.0 cr)
• BMEN 8041 - Advanced Tissue Engineering Lab (3.0 cr)
• BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
• BMEN 8151 - Biomedical Electronics and Implantable Microsystems (3.0 cr)
• BMEN 8201 - Advanced Tissue Mechanics (3.0 cr)
• BMEN 8381 - Bioheat and Mass Transfer (3.0 cr)
• BMEN 8421 - Biophotonics (3.0 cr)
• BMEN 8431 - Advanced Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
• BMEN 8501 - Dynamical Systems in Biology (3.0 cr)
• BMEN 8502 - Physiological Control Systems (3.0 cr)
• BMEN 8511 - Systems and Synthetic Biology (3.0 cr)

BME Seminar
Seminars are 1 credit per semester, repeatable for credit, and may be taken in any order.
Take 2 or more credit(s) from the following:
• BMEN 8601 - Biomedical Engineering Seminar (1.0 cr)
• BMEN 8602 - Biomedical Engineering Seminar (1.0 cr)

Biology Electives
Additional courses may be approved by the director of graduate studies.
Take 6 or more credit(s) from the following:
• BIOC 5216 - Current Topics in Signal Transduction (3.0 cr)
• BIOC 5444 - Muscle (3.0 cr)
• BIOC 6021 - Biochemistry (3.0 cr)
• BIOC 8002 - Molecular Biology and Regulation of Biological Processes (3.0 cr)
• BIOC 8216 - Signal Transduction and Gene Expression (3.0 cr)
• BMEN 5501 - Biology for Biomedical Engineers (3.0 cr)
• BMEN 5701 - Cancer Bioengineering (3.0 cr)
• BMEN 8041 - Advanced Tissue Engineering Lab (3.0 cr)
• CGSC 8041 - Cognitive Neuroscience (4.0 cr)
• CPMS 5101 - Introduction to Clinical Physiology and Movement Science (3.0 cr)
• EEB 5371 - Principles of Systematics (3.0 cr)
• GCD 5036 - Molecular Cell Biology (3.0 cr)
• GCD 8008 - Mammalian Gene Transfer and Genome Engineering (2.0 cr)
• GCD 8103 - Human Histology (5.0 cr)
• GCD 8131 - Advanced Molecular Genetics and Genomics (3.0 cr)
• GCD 8151 - Cellular Biochemistry and Cell Biology (2.0 - 4.0 cr)
• GCD 8161 - Advanced Cell Biology and Development (3.0 cr)
• MEDC 5245 - Introduction to Drug Design (3.0 cr)
• MEDC 8461 - Design of Cancer Therapeutics (3.0 cr)
• MEDC 8760 - Design of Peptidomimetics (2.0 cr)
• MICA 8002 - Structure, Function, and Genetics of Bacteria and Viruses (4.0 cr)
• MICA 8003 - Immunity and Immunopathology (4.0 cr)
• MICA 8004 - Cellular and Cancer Biology (4.0 cr)
• MICA 8009 - Biochemical Aspects of Normal and Abnormal Cell Growth and Cell Death (2.0 cr)
• MLSP 5111 - Concepts of Diagnostic Microbiology (3.0 cr)
• MLSP 5511 - Principles of Immunobiology (3.0 cr)
• MPHY 5172 - Radiation Biology (3.0 cr)
• NSC 5290 - Cerebrovascular Hemodynamics and Diseases I (4.0 cr)
• NSC 5461 - Cellular and Molecular Neuroscience (4.0 cr)
• NSC 5540 - Survey of Biomedical Neuroscience (2.0 cr)
• NSC 5561 - Systems Neuroscience (4.0 cr)
• NSC 5661W - Behavioral Neuroscience [WI] (3.0 cr)
• NSC 5667 - Neurobiology of Disease (2.0 - 3.0 cr)
• NSC 8211 - Developmental Neurobiology (3.0 cr)
• NSC 8221 - Neurobiology of Pain and Analgesia (3.0 cr)
• NSCI 5101 - Neurobiology I: Molecules, Cells, and Systems (3.0 cr)
• OBIO 8012 - Basic Concepts in Skeletal Biology (2.0 cr)
• OBIO 8028 - Molecular Basis of Cellular and Microbial Adhesion (2.0 cr)
• PHAR 5700 - Applied Fundamentals of Pharmacotherapy (3.0 cr)
• PHSL 5061 - Principles of Physiology for Biomedical Engineering (4.0 cr)
• PHSL 5115 - Clinical Physiology I (3.0 cr)
• PHSL 5116 - Clinical Physiology II (3.0 cr)
• PHSL 5444 - Muscle (3.0 cr)
• PHSL 5510 - Advanced Cardiac Physiology and Anatomy (2.0 - 3.0 cr)
• PHSL 5525 - Anatomy and Physiology of the Pelvis and Urinary System (1.0 - 2.0 cr)
• PSY 5015 - Cognition, Computation, and Brain (3.0 cr)
• PSY 5062 - Cognitive Neuropsychology (3.0 cr)
• PSY 8041 - Proseminar in Perception (3.0 cr)
• RSC 5200 - Introduction to Neuromodulation (1.0 - 3.0 cr)
• RSC 5231 - Clinical Biomechanics (2.0 - 5.0 cr)
• RSC 5281 - Scientific Foundations: Exercise Theory (3.0 cr)
• RSC 8282 - Problems in Human Movement (4.0 cr)
• SCB 8181 - Stem Cell Biology (3.0 cr)
• SLHS 5808 - Pathophysiology of Hearing Disorders (3.0 cr)

Technical Electives
PLAN A students must take 6 or more Technical Elective credits. PLAN B and PLAN C students must take 9 or more Technical Elective credits. Additional courses may be approved by the director of graduate studies.

Take 6 or more credits from the following:
• AEM 5401 - Intermediate Dynamics (3.0 cr)
• AEM 5451 - Optimal Estimation (3.0 cr)
• AEM 5501 - Continuum Mechanics (3.0 cr)
• AEM 5503 - Theory of Elasticity (3.0 cr)
• AEM 8511 - Advanced Topics in Continuum Mechanics (3.0 cr)
• AEM 8531 - Fracture Mechanics (3.0 cr)
• BIO 5351 - Protein Engineering (3.0 cr)
• BIO 5352 - Biotechnology and Bioengineering for Biochemists (3.0 cr)
• BIO 5528 - Spectroscopy and Kinetics (4.0 cr)
• BIO 8005 - Biochemistry: Structure and Catalysis (2.0 cr)
• BMEN 5001 - Advanced Biomaterials (3.0 cr)
• BMEN 5041 - Tissue Engineering (3.0 cr)
• BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
• BMEN 5111 - Biomedical Ultrasound (3.0 cr)
• BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
• BMEN 5201 - Advanced Biomechanics (3.0 cr)
• BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
• BMEN 5321 - Microfluidics in Biology and Medicine (3.0 cr)
• BMEN 5351 - Cell Engineering (3.0 cr)
• BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
• BMEN 5411 - Neural Engineering (3.0 cr)
• BMEN 5412 - Neuromodulation (3.0 cr)
• BMEN 5413 - Neural Decoding and Interfacing (3.0 cr)
• BMEN 5421 - Introduction to Biomedical Optics (3.0 cr)
• BMEN 5601 - Cardiovascular Devices (1.0 cr)
• BMEN 8001 - Polymeric Biomaterials (3.0 cr)
• BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
• BMEN 8151 - Biomedical Electronics and Implantable Microsystems (3.0 cr)
• BMEN 8201 - Advanced Tissue Mechanics (3.0 cr)
• BMEN 8381 - Bioheat and Mass Transfer (3.0 cr)
• BMEN 8401 - New Product Design and Business Development (4.0 cr)
• BMEN 8421 - Biophotonics (3.0 cr)
• BMEN 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
• BMEN 8501 - Dynamical Systems in Biology (3.0 cr)
• BMEN 8502 - Physiological Control Systems (3.0 cr)
• BMEN 8511 - Systems and Synthetic Biology (3.0 cr)
• CHEM 8021 - Computational Chemistry (4.0 cr)
• CHEM 8157 - Bioanalytical Chemistry (4.0 cr)
• CHEN 5751 - Biochemical Engineering (3.0 cr)
• CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
• CHEN 8201 - Applied Math (3.0 cr)
• CHEN 8221 - Synthetic Polymer Chemistry (4.0 cr)
CHEN 8301 - Physical Rate Processes I: Transport (3.0 cr)
CHEN 8402 - Statistical Thermodynamics and Kinetics (3.0 cr)
CHEN 8754 - Systems Analysis of Biological Processes (3.0 cr)
CSCI 5103 - Operating Systems (3.0 cr)
CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
CSCI 5511 - Artificial Intelligence I (3.0 cr)
CSCI 5521 - Introduction to Machine Learning (3.0 cr)
CSCI 5523 - Introduction to Data Mining (3.0 cr)
CSCI 5525 - Machine Learning (3.0 cr)
CSCI 5551 - Introduction to Intelligent Robotic Systems (3.0 cr)
EE 5141 - Introduction to Microsystem Technology (4.0 cr)
EE 5171 - Microelectronic Fabrication (4.0 cr)
EE 5251 - Optimal Filtering and Estimation (3.0 cr)
EE 5323 - VLSI Design I (3.0 cr)
EE 5333 - Analog Integrated Circuit Design (3.0 cr)
EE 5393 - Circuits, Computation, and Biology (3.0 cr)
EE 5551 - Probability and Stochastic Processes (3.0 cr)
EE 5542 - Adaptive Digital Signal Processing (3.0 cr)
EE 5545 - Digital Signal Processing Design (3.0 cr)
EE 5561 - Image Processing and Applications (3.0 cr)
EE 5601 - Introduction to RF/Microwave Engineering (3.0 cr)
EE 5621 - Physical Optics (3.0 cr)
EE 5691 - Predictive Learning from Data (3.0 cr)
HINF 5430 - Foundations of Health Informatics I (3.0 cr)
HINF 5431 - Foundations of Health Informatics II (3.0 cr)
HUMF 5001 - Foundations of Human Factors/Ergonomics (3.0 cr)
HUMF 5211 - Human Factors and Work Analysis (4.0 cr)
IE 5111 - Systems Engineering I (2.0 cr)
IE 5113 - Systems Engineering II (4.0 cr)
IE 5511 - Human Factors and Work Analysis (4.0 cr)
IE 5522 - Quality Engineering and Reliability (4.0 cr)
IE 5541 - Project Management (4.0 cr)
IE 5545 - Decision Analysis (4.0 cr)
IE 5553 - Simulation (4.0 cr)
KIN 5001 - Foundations of Human Factors/Ergonomics (3.0 cr)
KIN 5643 - Applied Motion Capture and Movement Analysis Technology (3.0 cr)
MATH 5248 - Cryptology and Number Theory (4.0 cr)
MATH 5445 - Mathematical Analysis of Biological Networks (4.0 cr)
MATH 5447 - Theoretical Neuroscience (4.0 cr)
MATH 5587 - Elementary Partial Differential Equations I (4.0 cr)
MATH 5651 - Basic Theory of Probability and Statistics (4.0 cr)
MATH 5652 - Introduction to Stochastic Processes (4.0 cr)
MATH 8202 - General Algebra (3.0 cr)
MATH 8253 - Algebraic Geometry (3.0 cr)
MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
MATS 8003 - Electronic Properties (3.0 cr)
ME 5228 - Introduction to Finite Element Modeling, Analysis, and Design (4.0 cr)
ME 5241 - Computer-Aided Engineering (4.0 cr)
ME 5243 - Advanced Mechanism Design (4.0 cr)
ME 5247 - Stress Analysis, Sensing, and Transducers (4.0 cr)
ME 5281 - Analog and Digital Control (4.0 cr)
ME 5286 - Robotics (4.0 cr)
ME 5341 - Case Studies in Thermal Engineering and Design (4.0 cr)
ME 5351 - Computational Heat Transfer (4.0 cr)
ME 8254 - Fundamentals of Microelectromechanical Systems (MEMS) (4.0 cr)
ME 8341 - Conduction (3.0 cr)
ME 8342 - Convection (3.0 cr)
ME 8343 - Radiation (3.0 cr)
ME 8345 - Computational Heat Transfer and Fluid Flow (3.0 cr)
MPHY 5170 - Basic Radiological Physics (3.0 cr)
MPHY 5178 - Physical Principles of Magnetic Resonance Imaging (3.0 cr)
MPHY 8147 - Advanced Physics of Magnetic Resonance Imaging (MRI) (3.0 cr)
NSC 5202 - Theoretical Neuroscience: Systems and Information Processing (3.0 cr)
• NSCI 5300 - Biological Microscopy & Digital Imaging (3.0 cr)
• PHM 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
• PHYS 5081 - Introduction to Biopolymer Physics (3.0 cr)
• PHYS 5402 - Radiological Physics (4.0 cr)
• PSY 5038W - Introduction to Neural Networks [WI] (3.0 cr)
• PSY 5065 - Functional Imaging: Hands-on Training (3.0 cr)
• PUBH 6415 - Biostatistical Methods II (3.0 cr)
• PUBH 6450 - Biostatistics I (4.0 cr)
• PUBH 6451 - Biostatistics II (4.0 cr)
• PUBH 7440 - Introduction to Bayesian Analysis (3.0 cr)
• PUBH 7475 - Statistical Learning and Data Mining (3.0 cr)
• RSC 5135 - Advanced Biomechanics I: Kinematics (3.0 cr)
• RSC 5235 - Advanced Biomechanics II: Kinetics (3.0 cr)
• RSC 5841 - Applied Data Acquisition and Processing (3.0 cr)
• RSC 8135 - Human Kinematics (3.0 cr)
• RSC 8235 - Human Kinetics (3.0 cr)
• STAT 5021 - Statistical Analysis (4.0 cr)
• STAT 5101 - Theory of Statistics I (4.0 cr)
• STAT 5102 - Theory of Statistics II (4.0 cr)
• STAT 5302 - Applied Regression Analysis (4.0 cr)
• STAT 5303 - Designing Experiments (4.0 cr)

Free Electives
PLAN A students are not required to take any Free Electives; PLAN B students must take at least 5 credits; PLAN C students must take at least 7 credits. Additional courses may be approved by the director of graduate studies.

Take 0 or more credit(s) from the following:
• BMEN 8402 - New Product Design and Business Development (4.0 cr)
• MILI 5589 - Medical Technology Evaluation and Market Research (2.0 cr)
• MOT 5001 - Technological Business Fundamentals (2.0 cr)
• MOT 5002 - Creating Technological Innovation (2.0 cr)
• MOT 5003 - Technological Business Planning Workshop (1.0 cr)
• PDES 5701 - Creativity, Idea Generation, and Innovation (3.0 cr)
• PDES 5702 - Concept Sketching and Rendering (3.0 cr)
• PDES 5704 - Computer-Aided Design Methods (3.0 cr)
• PHYS 5401 - Physiological Physics (4.0 cr)
• PSY 5036W - Computational Vision [WI] (3.0 cr)
• PUBH 6161 - Regulatory Toxicology (2.0 cr)
• PUBH 6414 - Biostatistical Literacy (3.0 cr)
• PUBH 7415 - Introduction to Clinical Trials (3.0 cr)
• RSC 5106 - Introduction to Rehabilitation Science (1.0 cr)

• Additional Bio/Tech/Core
• Any course(s) from the BMEn Core, Biology Elective, and/or Technical Elective lists that are not being used toward another degree requirement.

• Coursework Relevant to Science and Technology
Max 3 credits in coursework relevant to science and technology (e.g., public policy, ethical/historical aspects, etc).

Take 0 - 3 credit(s) from the following:
• BTHX 5100 - Introduction to Clinical Ethics (3.0 cr)
• BTHX 5120 - Dying in Contemporary Medical Culture (2.0 cr)
• BTHX 5210 - Ethics of Human Subjects Research (3.0 cr)
• BTHX 5300 - Foundations of Bioethics (3.0 cr)
• BTHX 5325 - Biomedical Ethics (3.0 cr)
• BTHX 5650 - Disability Ethics (3.0 cr)
• BTHX 8120 - Dying in Contemporary Medical Culture (2.0 cr)
• MILI 6235 - Pharmaceutical Industry: Business and Policy (2.0 cr)
• MILI 6995 - Medical Industry Valuation Laboratory (2.0 cr)
• PHAR 5200 - Drugs and the US Health Care System (3.0 cr)

• Math-/Statistics-Intensive
Included in the Core and/or Elective coursework must be at least 3 credits designated as Math-/Statistics-Intensive. These are not additional credits but will overlap with coursework already satisfying the BMEn Core, Technical Elective, and/or Free Elective requirements. Additional courses may be approved by the director of graduate studies.

Take 3 or more credit(s) from the following:
• AEM 5451 - Optimal Estimation (3.0 cr)
• AEM 5501 - Continuum Mechanics (3.0 cr)
• AEM 5503 - Theory of Elasticity (3.0 cr)
• AEM 8511 - Advanced Topics in Continuum Mechanics (3.0 cr)
• BMEN 5111 - Biomedical Ultrasound (3.0 cr)
• BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
• BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
• BMEN 8201 - Advanced Tissue Mechanics (3.0 cr)
• BMEN 8381 - Bioheat and Mass Transfer (3.0 cr)
• BMEN 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
• BMEN 8501 - Dynamical Systems in Biology (3.0 cr)
• BMEN 8502 - Physiological Control Systems (3.0 cr)
• CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
• CHEN 8201 - Applied Math (3.0 cr)
• CHEN 8402 - Statistical Thermodynamics and Kinetics (3.0 cr)
• CHEN 8754 - Systems Analysis of Biological Processes (3.0 cr)
• CSCI 5521 - Introduction to Machine Learning (3.0 cr)
• CSCI 5525 - Machine Learning (3.0 cr)
• EE 5251 - Optimal Filtering and Estimation (3.0 cr)
• EE 5531 - Probability and Stochastic Processes (3.0 cr)
• EE 5542 - Adaptive Digital Signal Processing (3.0 cr)
• EE 5545 - Digital Signal Processing Design (3.0 cr)
• EE 5561 - Image Processing and Applications (3.0 cr)
• EE 5601 - Introduction to RF/Microwave Engineering (3.0 cr)
• EE 5621 - Physical Optics (3.0 cr)
• EE 8591 - Predictive Learning from Data (3.0 cr)
• IE 5522 - Quality Engineering and Reliability (4.0 cr)
• MATH 5248 - Cryptology and Number Theory (4.0 cr)
• MATH 5445 - Mathematical Analysis of Biological Networks (4.0 cr)
• MATH 5447 - Theoretical Neuroscience (4.0 cr)
• MATH 5587 - Elementary Partial Differential Equations I (4.0 cr)
• MATH 5651 - Basic Theory of Probability and Statistics (4.0 cr)
• MATH 5652 - Introduction to Stochastic Processes (4.0 cr)
• MATH 8202 - General Algebra (3.0 cr)
• MATH 8253 - Algebraic Geometry (3.0 cr)
• ME 5228 - Introduction to Finite Element Modeling, Analysis, and Design (4.0 cr)
• ME 5351 - Computational Heat Transfer (4.0 cr)
• ME 8341 - Conduction (3.0 cr)
• ME 8342 - Convection (3.0 cr)
• ME 8343 - Radiation (3.0 cr)
• ME 8345 - Computational Heat Transfer and Fluid Flow (3.0 cr)
• MPHY 8147 - Advanced Physics of Magnetic Resonance Imaging (MRI) (3.0 cr)
• PHM 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
• PSY 5038W - Introduction to Neural Networks [WI] (3.0 cr)
• PUBH 6450 - Biostatistics I (4.0 cr)
• PUBH 6451 - Biostatistics II (4.0 cr)
• PUBH 7440 - Introduction to Bayesian Analysis (3.0 cr)
• PUBH 7475 - Statistical Learning and Data Mining (3.0 cr)
• STAT 5021 - Statistical Analysis (4.0 cr)
• STAT 5101 - Theory of Statistics I (4.0 cr)
• STAT 5102 - Theory of Statistics II (4.0 cr)
• STAT 5302 - Applied Regression Analysis (4.0 cr)
• STAT 5303 - Designing Experiments (4.0 cr)

Thesis/Project Requirements

PLAN A
Take 10 or more credit(s) from the following:
• BMEN 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

- OR -

PLAN B
Take 2 or more credit(s) from the following:
• BMEN 8820 - Plan B Project (2.0 - 3.0 cr)
A sub-plan is not required for this program. Students may not complete the program with more than one sub-plan.

**Combined B.Bm.E./M.S.**

The College Science & Engineering offers an early-admission opportunity for eligible University of Minnesota B.Bm.E. students also interested in completing the Biomedical Engineering MS degree (Plan A or Plan B only). The Early Admission sub-plan, also referred to as the Combined B.Bm.E./MS Biomedical Engineering program, enables B.Bm.E. majors to take 3-16 credits toward the MS requirements during their senior (fourth) year, in addition to the courses required for the B.Bm.E. degree. The MS degree may then be completed in the fifth year of study. Students are NOT permitted to count a single course toward both the undergraduate and graduate degrees; each course must be counted either toward the B.Bm.E. requirements or the MS requirements.

Interested B.Bm.E. students should visit the program website at http://bme.umn.edu/grad/appcombined.html for detailed application and admission information, deadlines, and instructions.

Students admitted to the Combined B.Bm.E./M.S. must maintain timely degree progress to ensure that all undergraduate degree requirements are completed by the end of their fourth year. They must also be able to take additional courses during their senior year, beyond those required by the B.Bm.E. curriculum, to be eligible for this program.
Twin Cities Campus
Biomedical Engineering Minor

Department of Biomedical Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Biomedical Engineering Graduate Program, 7-105 Nils Hasselmo Hall, 312 Church Street S.E., Minneapolis, MN 55455 (612-624-8396; fax: 612-626-6583)
Email: bmenqs@umn.edu
Website: http://bme.umn.edu/grad

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Biomedical engineering is the application of engineering principles and methods to problems in biology and medicine. The discipline includes the study of fundamental processes in biology and physiology, the study of the diagnosis and treatment of disease and injury, and the design and development of medical devices and techniques. Students take courses in mathematics, biology, biomedical engineering, and areas of science and engineering that are relevant for the degree objectives.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

All courses for the biomedical engineering minor must be completed for a letter grade (A-F). A minimum grade of B- is required for a course to count toward the minor.

Program Sub-plans
Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

Master's
BMEn Core
Take 1 or more course(s) from the following:
- BMEN 5001 - Advanced Biomaterials (3.0 cr)
- BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
- BMEN 5201 - Advanced Biomechanics (3.0 cr)
- BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
- BMEN 5351 - Cell Engineering (3.0 cr)
- BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
- BMEN 8001 - Polymeric Biomaterials (3.0 cr)
- BMEN 8041 - Advanced Tissue Engineering Lab (3.0 cr)
- BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
- BMEN 8151 - Biomedical Electronics and Implantable Microsystems (3.0 cr)
- BMEN 8201 - Advanced Tissue Mechanics (3.0 cr)
- BMEN 8381 - Bioheat and Mass Transfer (3.0 cr)
- BMEN 8421 - Biophotonics (3.0 cr)
- BMEN 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
- BMEN 8501 - Dynamical Systems in Biology (3.0 cr)
- BMEN 8502 - Physiological Control Systems (3.0 cr)
- BMEN 8511 - Systems and Synthetic Biology (3.0 cr)

**Additional BMEn Graduate Course(s)**

Three additional graduate level BMEn credits are required. Coursework from the BMEn Core list can be applied toward this requirement. The following courses cannot be used to satisfy any minor requirements: BMEn 8334, 8335, 8601, 8602, 8611, 8710, 8720, 8820, 8910.

- Take 1 or more course(s) from the following:
  - BMEN 5xxx
  - BMEN 8xxx

**Doctoral**

The Ph.D. minor in BME requires two courses from the BMEn Core list, one course from the Biology Electives list, and one course from the Technical Electives list, for a minimum of 12 credits.

A single course may not be counted toward more than one requirement.

**BMEn Core**

- Take 2 or more course(s) from the following:
  - BMEN 5001 - Advanced Biomaterials (3.0 cr)
  - BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
  - BMEN 5201 - Advanced Biomechanics (3.0 cr)
  - BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
  - BMEN 5351 - Cell Engineering (3.0 cr)
  - BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
  - BMEN 8001 - Polymeric Biomaterials (3.0 cr)
  - BMEN 8041 - Advanced Tissue Engineering Lab (3.0 cr)
  - BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
  - BMEN 8151 - Biomedical Electronics and Implantable Microsystems (3.0 cr)
  - BMEN 8201 - Advanced Tissue Mechanics (3.0 cr)
  - BMEN 8381 - Bioheat and Mass Transfer (3.0 cr)
  - BMEN 8421 - Biophotonics (3.0 cr)
  - BMEN 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
  - BMEN 8501 - Dynamical Systems in Biology (3.0 cr)
  - BMEN 8502 - Physiological Control Systems (3.0 cr)
  - BMEN 8511 - Systems and Synthetic Biology (3.0 cr)

**Biology Elective**

Additional courses may be approved by the director of graduate studies.

- Take 1 or more course(s) from the following:
  - BIOC 5216 - Current Topics in Signal Transduction (3.0 cr)
  - BIOC 5444 - Muscle (3.0 cr)
  - BIOC 5021 - Biochemistry (3.0 cr)
  - BIOC 8002 - Molecular Biology and Regulation of Biological Processes (3.0 cr)
  - BIOC 8216 - Signal Transduction and Gene Expression (3.0 cr)
  - BMEN 5501 - Biology for Biomedical Engineers (3.0 cr)
  - BMEN 5701 - Cancer Bioengineering (3.0 cr)
  - BMEN 8041 - Advanced Tissue Engineering Lab (3.0 cr)
  - CGSC 8041 - Cognitive Neuroscience (4.0 cr)
  - CPMS 5101 - Introduction to Clinical Physiology and Movement Science (3.0 cr)
  - EEB 5371 - Principles of Systematics (3.0 cr)
  - GCD 5036 - Molecular Cell Biology (3.0 cr)
  - GCD 8008 - Mammalian Gene Transfer and Genome Engineering (2.0 cr)
  - GCD 8103 - Human Histology (5.0 cr)
  - GCD 8131 - Advanced Molecular Genetics and Genomics (3.0 cr)
  - GCD 8151 - Cellular Biochemistry and Cell Biology (2.0 - 4.0 cr)
  - GCD 8161 - Advanced Cell Biology and Development (3.0 cr)
  - MEDC 5245 - Introduction to Drug Design (3.0 cr)
  - MEDC 8461 - Design of Cancer Therapeutics (3.0 cr)
  - MEDC 8760 - Design of Peptidomimetics (2.0 cr)
  - MICA 8002 - Structure, Function, and Genetics of Bacteria and Viruses (4.0 cr)
• MICA 8003 - Immunity and Immunopathology (4.0 cr)
• MICA 8004 - Cellular and Cancer Biology (4.0 cr)
• MICA 8009 - Biochemical Aspects of Normal and Abnormal Cell Growth and Cell Death (2.0 cr)
• MLSP 5111 - Concepts of Diagnostic Microbiology (3.0 cr)
• MLSP 5511 - Principles of Immunobiology (3.0 cr)
• MPHYS 5712 - Radiation Biology (3.0 cr)
• NEUR 5230 - Cerebrovascular Hemodynamics and Diseases I (4.0 cr)
• NSC 5461 - Cellular and Molecular Neuroscience (4.0 cr)
• NSC 5540 - Survey of Biomedical Neuroscience (2.0 cr)
• NSC 5561 - Systems Neuroscience (4.0 cr)
• NSC 5661W - Behavioral Neuroscience [WI] (3.0 cr)
• NSC 5667 - Neurobiology of Disease (2.0 - 3.0 cr)
• NSC 8211 - Developmental Neurobiology (3.0 cr)
• NSC 8221 - Neurobiology of Pain and Analgesia (3.0 cr)
• NSCI 5101 - Neurobiology: Molecules, Cells, and Systems (3.0 cr)
• OBIO 5012 - Basic Concepts in Skeletal Biology (2.0 cr)
• OBIO 8028 - Molecular Basis of Cellular and Microbial Adhesion (2.0 cr)
• PHAR 5700 - Applied Fundamentals of Pharmacotherapy (3.0 cr)
• PHSL 5061 - Principles of Physiology for Biomedical Engineering (4.0 cr)
• PHSL 5115 - Clinical Physiology I (3.0 cr)
• PHSL 5116 - Clinical Physiology II (3.0 cr)
• PHSL 5444 - Muscle (3.0 cr)
• PHSL 5510 - Advanced Cardiac Physiology and Anatomy (2.0 - 3.0 cr)
• PHSL 5525 - Anatomy and Physiology of the Pelvis and Urinary System (1.0 - 2.0 cr)
• PSY 5015 - Cognition, Computation, and Brain (3.0 cr)
• PSY 5062 - Cognitive Neuropsychology (3.0 cr)
• PSY 8041 - Proseminar in Perception (3.0 cr)
• RSC 5200 - Introduction to Neuromodulation (1.0 - 3.0 cr)
• RSC 5231 - Clinical Biomechanics (2.0 - 5.0 cr)
• RSC 5281 - Scientific Foundations: Exercise Theory (3.0 cr)
• RSC 8282 - Problems in Human Movement (4.0 cr)
• SCB 8181 - Stem Cell Biology (3.0 cr)
• SLHS 5808 - Pathophysiology of Hearing Disorders (3.0 cr)

Technical Elective
Additional courses may be approved by the director of graduate studies.
Take 1 or more course(s) from the following:
• AEM 5401 - Intermediate Dynamics (3.0 cr)
• AEM 5451 - Optimal Estimation (3.0 cr)
• AEM 5501 - Continuum Mechanics (3.0 cr)
• AEM 5503 - Theory of Elasticity (3.0 cr)
• AEM 8511 - Advanced Topics in Continuum Mechanics (3.0 cr)
• AEM 8531 - Fracture Mechanics (3.0 cr)
• BIOC 5352 - Biotechnology and Bioengineering for Biochemists (3.0 cr)
• BIOC 5528 - Spectroscopy and Kinetics (4.0 cr)
• BIOC 8005 - Biochemistry: Structure and Catalysis (2.0 cr)
• BMEN 5001 - Advanced Biomaterials (3.0 cr)
• BMEN 5041 - Tissue Engineering (3.0 cr)
• BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
• BMEN 5111 - Biomedical Ultrasound (3.0 cr)
• BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
• BMEN 5201 - Advanced Biomechanics (3.0 cr)
• BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
• BMEN 5321 - Microfluidics in Biology and Medicine (3.0 cr)
• BMEN 5351 - Cell Engineering (3.0 cr)
• BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
• BMEN 5411 - Neural Engineering (3.0 cr)
• BMEN 5412 - Neuromodulation (3.0 cr)
• BMEN 5413 - Neural Decoding and Interfacing (3.0 cr)
• BMEN 5421 - Introduction to Biomedical Optics (3.0 cr)
• BMEN 5601 - Cardiovascular Devices (1.0 cr)
• BMEN 8001 - Polymeric Biomaterials (3.0 cr)
• BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
• BMEN 8151 - Biomedical Electronics and Implantable Microsystems (3.0 cr)
• BMEN 8201 - Advanced Tissue Mechanics (3.0 cr)
• BMEN 8381 - Bioheat and Mass Transfer (3.0 cr)
• BMEN 8401 - New Product Design and Business Development (4.0 cr)
• BMEN 8421 - Biophotonics (3.0 cr)
• BMEN 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
• BMEN 8501 - Dynamical Systems in Biology (3.0 cr)
• BMEN 8502 - Physiological Control Systems (3.0 cr)
• BMEN 8511 - Systems and Synthetic Biology (3.0 cr)
• CHEM 8021 - Computational Chemistry (4.0 cr)
• CHEM 8157 - Bioanalytical Chemistry (4.0 cr)
• CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
• CHEN 8201 - Applied Math (3.0 cr)
• CHEN 8221 - Synthetic Polymer Chemistry (4.0 cr)
• CHEN 8301 - Physical Rate Processes I: Transport (3.0 cr)
• CHEN 8402 - Statistical Thermodynamics and Kinetics (3.0 cr)
• CHEN 8754 - Systems Analysis of Biological Processes (3.0 cr)
• CSCI 5103 - Operating Systems (3.0 cr)
• CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
• CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
• CSCI 5511 - Artificial Intelligence I (3.0 cr)
• CSCI 5521 - Introduction to Machine Learning (3.0 cr)
• CSCI 5523 - Introduction to Data Mining (3.0 cr)
• CSCI 5525 - Machine Learning (3.0 cr)
• CSCI 5551 - Introduction to Intelligent Robotic Systems (3.0 cr)
• EE 5141 - Introduction to Microsystem Technology (4.0 cr)
• EE 5171 - Microelectronic Fabrication (4.0 cr)
• EE 5251 - Optimal Filtering and Estimation (3.0 cr)
• EE 5323 - VLSI Design I (3.0 cr)
• EE 5333 - Analog Integrated Circuit Design (3.0 cr)
• EE 5393 - Circuits, Computation, and Biology (3.0 cr)
• EE 5531 - Probability and Stochastic Processes (3.0 cr)
• EE 5542 - Adaptive Digital Signal Processing (3.0 cr)
• EE 5545 - Digital Signal Processing Design (3.0 cr)
• EE 5561 - Image Processing and Applications (3.0 cr)
• EE 5601 - Introduction to RF/Microwave Engineering (3.0 cr)
• EE 5621 - Physical Optics (3.0 cr)
• EE 6591 - Predictive Learning from Data (3.0 cr)
• HINF 5430 - Foundations of Health Informatics I (3.0 cr)
• HINF 5431 - Foundations of Health Informatics II (3.0 cr)
• HUMF 5001 - Foundations of Human Factors/Ergonomics (3.0 cr)
• HUMF 5211 - Human Factors and Work Analysis (4.0 cr)
• IE 5111 - Systems Engineering I (2.0 cr)
• IE 5113 - Systems Engineering II (4.0 cr)
• IE 5511 - Human Factors and Work Analysis (4.0 cr)
• IE 5522 - Quality Engineering and Reliability (4.0 cr)
• IE 5541 - Project Management (4.0 cr)
• IE 5545 - Decision Analysis (4.0 cr)
• IE 5553 - Simulation (4.0 cr)
• KIN 5001 - Foundations of Human Factors/Ergonomics (3.0 cr)
• KIN 5643 - Applied Motion Capture and Movement Analysis Technology (3.0 cr)
• MATH 5248 - Cryptology and Number Theory (4.0 cr)
• MATH 5445 - Mathematical Analysis of Biological Networks (4.0 cr)
• MATH 5447 - Theoretical Neuroscience (4.0 cr)
• MATH 5587 - Elementary Partial Differential Equations I (4.0 cr)
• MATH 5581 - Basic Theory of Probability and Statistics (4.0 cr)
• MATH 5552 - Introduction to Stochastic Processes (4.0 cr)
• MATH 8202 - General Algebra (3.0 cr)
• MATH 8253 - Algebraic Geometry (3.0 cr)
• MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
• MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
• MATS 8003 - Electronic Properties (3.0 cr)
• ME 5228 - Introduction to Finite Element Modeling, Analysis, and Design (4.0 cr)
• ME 5241 - Computer-Aided Engineering (4.0 cr)
• ME 5243 - Advanced Mechanism Design (4.0 cr)
• ME 5247 - Stress Analysis, Sensing, and Transducers (4.0 cr)
• ME 5281 - Analog and Digital Control (4.0 cr)
• ME 5286 - Robotics (4.0 cr)
• ME 5341 - Case Studies in Thermal Engineering and Design (4.0 cr)
• ME 5351 - Computational Heat Transfer (4.0 cr)
• ME 8254 - Fundamentals of Microelectromechanical Systems (MEMS) (4.0 cr)
• ME 8341 - Conduction (3.0 cr)
• ME 8342 - Convection (3.0 cr)
• ME 8343 - Radiation (3.0 cr)
• ME 8345 - Computational Heat Transfer and Fluid Flow (3.0 cr)
• MPHY 5170 - Basic Radiological Physics (3.0 cr)
• MPHY 5178 - Physical Principles of Magnetic Resonance Imaging (3.0 cr)
• MPHY 8147 - Advanced Physics of Magnetic Resonance Imaging (MRI) (3.0 cr)
• NSC 5202 - Theoretical Neuroscience: Systems and Information Processing (3.0 cr)
• NSCI 5300 - Biological Microscopy & Digital Imaging (3.0 cr)
• PHM 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
• PHYS 5081 - Introduction to Biopolymer Physics (3.0 cr)
• PHYS 5402 - Radiological Physics (4.0 cr)
• PSY 5038W - Introduction to Neural Networks [WI] (3.0 cr)
• PSY 5065 - Functional Imaging: Hands-on Training (3.0 cr)
• PUBH 6415 - Biostatistical Methods II (3.0 cr)
• PUBH 6450 - Biostatistics I (4.0 cr)
• PUBH 6451 - Biostatistics II (4.0 cr)
• PUBH 7440 - Introduction to Bayesian Analysis (3.0 cr)
• PUBH 7475 - Statistical Learning and Data Mining (3.0 cr)
• RSC 5135 - Advanced Biomechanics I: Kinematics (3.0 cr)
• RSC 5235 - Advanced Biomechanics II: Kinetics (3.0 cr)
• RSC 5841 - Applied Data Acquisition and Processing (3.0 cr)
• RSC 8135 - Human Kinematics (3.0 cr)
• RSC 8235 - Human Kinetics (3.0 cr)
• STAT 5021 - Statistical Analysis (4.0 cr)
• STAT 5101 - Theory of Statistics I (4.0 cr)
• STAT 5102 - Theory of Statistics II (4.0 cr)
• STAT 5302 - Applied Regression Analysis (4.0 cr)
• STAT 5303 - Designing Experiments (4.0 cr)
Biomedical engineering is the application of engineering principles and methods to problems in biology and medicine. The discipline includes the study of fundamental processes in biology and physiology, the study of the diagnosis and treatment of disease and injury, and the design and development of medical devices and techniques. Students take courses in mathematics, biology, biomedical engineering, and areas of science and engineering that are relevant for the degree objectives.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.50.

A baccalaureate degree in engineering or in a physical or biological science is required.

Other requirements to be completed before admission:
Applicants with an engineering degree do not need to complete any specific coursework prior to applying. Applicants without an engineering degree must complete (1) math coursework through calculus I, calculus II, linear algebra, and differential equations; and (2) at least one year of college-level physics, preferably calculus-based.

There are no minimum required GPA, GRE, or English language test scores. A GPA of at least 3.5 on a 4.0 scale is preferred, but not required. Applicants with a lower GPA may still apply, but they will have a much lower chance of admission.

Special Application Requirements:
Fall application deadline is December 15. PhD applications are not accepted for the spring or summer terms. Application instructions are available at http://bme.umn.edu/grad/appinfo.html.

Applicants must submit their test score(s) from the following:
• GRE

International applicants must submit score(s) from one of the following tests:
• TOEFL
• IELTS

The preferred English language test is Test of English as Foreign Language

Key to test abbreviations (GRE, TOEFL, IELTS).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.
Program Requirements
11 to 30 credits are required in the major.
0 to 19 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

The PhD program requires 30 credits of coursework in mathematics, biology, biomedical engineering, and relevant areas of science and engineering.

BMEn Core - 6 credits
BMEn Seminars - 3 credits
Biology Electives - 6 credits
Technical Electives - 9 credits
Free Electives - 6 credits

A single course may NOT be counted simultaneously toward more than one of the requirements listed above.

Math/Statistics - Included in the Core/Elective requirements listed above must be a minimum of 6 credits designated as Math-/Statistics-Intensive. These are not additional credits but will overlap with coursework already satisfying the BMEn Core, Technical Elective, and/or Free Elective requirements.

Approved courses for each category are listed below. All coursework (excluding seminars and internships) must be taken for a letter grade (A-F). A minimum grade of B- is required for coursework to be counted toward degree requirements.

In addition to the 30 credits of coursework, 24 thesis credits (BMEn 8888) are required.

BMEn 8000-Level Core
Take 6 or more credit(s) from the following:
- BMEN 8001 - Polymeric Biomaterials (3.0 cr)
- BMEN 8041 - Advanced Tissue Engineering Lab (3.0 cr)
- BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
- BMEN 8151 - Biomedical Electronics and Implantable Microsystems (3.0 cr)
- BMEN 8201 - Advanced Tissue Mechanics (3.0 cr)
- BMEN 8381 - Bioheat and Mass Transfer (3.0 cr)
- BMEN 8421 - Biophotonics (3.0 cr)
- BMEN 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
- BMEN 8501 - Dynamical Systems in Biology (3.0 cr)
- BMEN 8502 - Physiological Control Systems (3.0 cr)
- BMEN 8511 - Systems and Synthetic Biology (3.0 cr)

BMEn Seminars
Seminars are 1 credit per semester, repeatable for credit, and may be taken in any order. Another department/program graduate seminar may be substituted for 1 credit of this requirement, with prior approval from the director of graduate studies.
Take 3 or more credit(s) from the following:
- BMEN 8601 - Biomedical Engineering Seminar (1.0 cr)
- BMEN 8602 - Biomedical Engineering Seminar (1.0 cr)

Biology Electives
Additional courses may be approved by the director of graduate studies.
Take 6 or more credit(s) from the following:
- BIOC 5216 - Current Topics in Signal Transduction (3.0 cr)
- BIOC 5444 - Muscle (3.0 cr)
- BIOC 6021 - Biochemistry (3.0 cr)
- BIOC 8002 - Molecular Biology and Regulation of Biological Processes (3.0 cr)
- BIOC 8216 - Signal Transduction and Gene Expression (3.0 cr)
- BMEN 5501 - Biology for Biomedical Engineers (3.0 cr)
- BMEN 5701 - Cancer Bioengineering (3.0 cr)
• BMEN 8041 - Advanced Tissue Engineering Lab (3.0 cr)
• CGSC 8041 - Cognitive Neuroscience (4.0 cr)
• CPMS 5101 - Introduction to Clinical Physiology and Movement Science (3.0 cr)
• EEB 5371 - Principles of Systematics (3.0 cr)
• GCD 5036 - Molecular Cell Biology (3.0 cr)
• GCD 8008 - Mammalian Gene Transfer and Genome Engineering (2.0 cr)
• GCD 8103 - Human Histology (5.0 cr)
• GCD 8131 - Advanced Molecular Genetics and Genomics (3.0 cr)
• GCD 8151 - Cellular Biochemistry and Cell Biology (2.0 - 4.0 cr)
• GCD 8161 - Advanced Cell Biology and Development (3.0 cr)
• MEDC 5245 - Introduction to Drug Design (3.0 cr)
• MEDC 8461 - Design of Cancer Therapeutics (3.0 cr)
• MEDC 8760 - Design of Peptidomimetics (2.0 cr)
• MICA 8002 - Structure, Function, and Genetics of Bacteria and Viruses (4.0 cr)
• MICA 8003 - Immunity and Immunopathology (4.0 cr)
• MICA 8004 - Cellular and Cancer Biology (4.0 cr)
• MICA 8009 - Biochemical Aspects of Normal and Abnormal Cell Growth and Cell Death (2.0 cr)
• MLSP 5111 - Concepts of Diagnostic Microbiology (3.0 cr)
• MLSP 5511 - Principles of Immunobiology (3.0 cr)
• MPHY 5172 - Radiation Biology (3.0 cr)
• NEUR 5230 - Cerebrovascular Hemodynamics and Diseases I (4.0 cr)
• NSC 5461 - Cellular and Molecular Neuroscience (4.0 cr)
• NSC 5540 - Survey of Biomedical Neuroscience (2.0 cr)
• NSC 5561 - Systems Neuroscience (4.0 cr)
• NSC 5661W - Behavioral Neuroscience [WI] (3.0 cr)
• NSC 5667 - Neurobiology of Disease (2.0 - 3.0 cr)
• NSC 8211 - Developmental Neurobiology (3.0 cr)
• NSC 8221 - Neurobiology of Pain and Analgesia (3.0 cr)
• NSCI 5101 - Neurobiology I: Molecules, Cells, and Systems (3.0 cr)
• OBIO 8012 - Basic Concepts in Skeletal Biology (2.0 cr)
• OBIO 8028 - Molecular Basis of Cellular and Microbial Adhesion (2.0 cr)
• PHAR 5700 - Applied Fundamentals of Pharmacotherapy (3.0 cr)
• PHSL 5061 - Principles of Physiology for Biomedical Engineering (4.0 cr)
• PHSL 5115 - Clinical Physiology I (3.0 cr)
• PHSL 5116 - Clinical Physiology II (3.0 cr)
• PHSL 5444 - Muscle (3.0 cr)
• PHSL 5510 - Advanced Cardiac Physiology and Anatomy (2.0 - 3.0 cr)
• PHSL 5525 - Anatomy and Physiology of the Pelvis and Urinary System (1.0 - 2.0 cr)
• PSY 5015 - Cognition, Computation, and Brain (3.0 cr)
• PSY 5062 - Cognitive Neuropsychology (3.0 cr)
• PSY 8041 - Proseminar in Perception (3.0 cr)
• RSC 5200 - Introduction to Neuromodulation (1.0 - 3.0 cr)
• RSC 5231 - Clinical Biomechanics (2.0 - 5.0 cr)
• RSC 5281 - Scientific Foundations: Exercise Theory (3.0 cr)
• RSC 8282 - Problems in Human Movement (4.0 cr)
• SCB 8181 - Stem Cell Biology (3.0 cr)
• SLHS 5808 - Pathophysiology of Hearing Disorders (3.0 cr)

Technical Electives
Additional courses may be approved by the director of graduate studies.
Take 9 or more credit(s) from the following:
• AEM 5401 - Intermediate Dynamics (3.0 cr)
• AEM 5451 - Optimal Estimation (3.0 cr)
• AEM 5501 - Continuum Mechanics (3.0 cr)
• AEM 5503 - Theory of Elasticity (3.0 cr)
• AEM 8511 - Advanced Topics in Continuum Mechanics (3.0 cr)
• AEM 8531 - Fracture Mechanics (3.0 cr)
• BIO 5351 - Protein Engineering (3.0 cr)
• BIO 5352 - Biotechnology and Bioengineering for Biochemists (3.0 cr)
• BIO 5528 - Spectroscopy and Kinetics (4.0 cr)
• BIO 8005 - Biochemistry: Structure and Catalysis (2.0 cr)
• BMEN 5001 - Advanced Biomaterials (3.0 cr)
• BMEN 5041 - Tissue Engineering (3.0 cr)
• BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
• BMEN 5111 - Biomedical Ultrasound (3.0 cr)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMEN 5151</td>
<td>Introduction to BioMEMS and Medical Microdevices (2.0 cr)</td>
</tr>
<tr>
<td>BMEN 5201</td>
<td>Advanced Biomechanics (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 5311</td>
<td>Advanced Biomedical Transport Processes (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 5321</td>
<td>Microfluidics in Biology and Medicine (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 5351</td>
<td>Cell Engineering (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 5401</td>
<td>Advanced Biomedical Imaging (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 5411</td>
<td>Neural Engineering (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 5412</td>
<td>Neurromodulation (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 5413</td>
<td>Neural Decoding and Interfacing (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 5421</td>
<td>Introduction to Biomedical Optics (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 5601</td>
<td>Cardiovascular Devices (1.0 cr)</td>
</tr>
<tr>
<td>BMEN 8001</td>
<td>Polymeric Biomaterials (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 8101</td>
<td>Biomedical Digital Signal Processing (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 8151</td>
<td>Biomedical Electronics and Implantable Microsystems (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 8201</td>
<td>Advanced Tissue Mechanics (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 8361</td>
<td>Bioheat and Mass Transfer (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 8401</td>
<td>New Product Design and Business Development (4.0 cr)</td>
</tr>
<tr>
<td>BMEN 8421</td>
<td>Biophotonics (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 8431</td>
<td>Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)</td>
</tr>
<tr>
<td>BMEN 8501</td>
<td>Dynamical Systems in Biology (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 8502</td>
<td>Physiological Control Systems (3.0 cr)</td>
</tr>
<tr>
<td>BMEN 8511</td>
<td>Systems and Synthetic Biology (3.0 cr)</td>
</tr>
<tr>
<td>CHEM 8021</td>
<td>Computational Chemistry (4.0 cr)</td>
</tr>
<tr>
<td>CHEM 8157</td>
<td>Bioanalytical Chemistry (4.0 cr)</td>
</tr>
<tr>
<td>CHEM 8181</td>
<td>Biochemical Engineering (3.0 cr)</td>
</tr>
<tr>
<td>CHEN 8201</td>
<td>Applied Math (3.0 cr)</td>
</tr>
<tr>
<td>CHEN 8221</td>
<td>Synthetic Polymer Chemistry (4.0 cr)</td>
</tr>
<tr>
<td>CHEN 8301</td>
<td>Physical Rate Processes I: Transport (3.0 cr)</td>
</tr>
<tr>
<td>CHEN 8402</td>
<td>Statistical Thermodynamics and Kinetics (3.0 cr)</td>
</tr>
<tr>
<td>CHEN 8754</td>
<td>Systems Analysis of Biological Processes (3.0 cr)</td>
</tr>
<tr>
<td>CSCI 5103</td>
<td>Operating Systems (3.0 cr)</td>
</tr>
<tr>
<td>CSCI 5211</td>
<td>Data Communications and Computer Networks (3.0 cr)</td>
</tr>
<tr>
<td>CSCI 5451</td>
<td>Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)</td>
</tr>
<tr>
<td>CSCI 5511</td>
<td>Artificial Intelligence I (3.0 cr)</td>
</tr>
<tr>
<td>CSCI 5521</td>
<td>Introduction to Machine Learning (3.0 cr)</td>
</tr>
<tr>
<td>CSCI 5523</td>
<td>Introduction to Data Mining (3.0 cr)</td>
</tr>
<tr>
<td>CSCI 5525</td>
<td>Machine Learning (3.0 cr)</td>
</tr>
<tr>
<td>CSCI 5551</td>
<td>Introduction to Intelligent Robotic Systems (3.0 cr)</td>
</tr>
<tr>
<td>EE 5141</td>
<td>Introduction to Microsystem Technology (4.0 cr)</td>
</tr>
<tr>
<td>EE 5171</td>
<td>Microelectronic Fabrication (4.0 cr)</td>
</tr>
<tr>
<td>EE 5251</td>
<td>Optimal Filtering and Estimation (3.0 cr)</td>
</tr>
<tr>
<td>EE 5323</td>
<td>VLSI Design I (3.0 cr)</td>
</tr>
<tr>
<td>EE 5333</td>
<td>Analog Integrated Circuit Design (3.0 cr)</td>
</tr>
<tr>
<td>EE 5393</td>
<td>Circuits, Computation, and Biology (3.0 cr)</td>
</tr>
<tr>
<td>EE 5531</td>
<td>Probability and Stochastic Processes (3.0 cr)</td>
</tr>
<tr>
<td>EE 5542</td>
<td>Adaptive Digital Signal Processing (3.0 cr)</td>
</tr>
<tr>
<td>EE 5545</td>
<td>Digital Signal Processing Design (3.0 cr)</td>
</tr>
<tr>
<td>EE 5561</td>
<td>Image Processing and Applications (3.0 cr)</td>
</tr>
<tr>
<td>EE 5601</td>
<td>Introduction to RF/Microwave Engineering (3.0 cr)</td>
</tr>
<tr>
<td>EE 5621</td>
<td>Physical Optics (3.0 cr)</td>
</tr>
<tr>
<td>EE 8591</td>
<td>Predictive Learning from Data (3.0 cr)</td>
</tr>
<tr>
<td>HINF 5430</td>
<td>Foundations of Health Informatics I (3.0 cr)</td>
</tr>
<tr>
<td>HINF 5431</td>
<td>Foundations of Health Informatics II (3.0 cr)</td>
</tr>
<tr>
<td>HUMF 5001</td>
<td>Foundations of Human Factors/Ergonomics (3.0 cr)</td>
</tr>
<tr>
<td>HUMF 5211</td>
<td>Human Factors and Work Analysis (4.0 cr)</td>
</tr>
<tr>
<td>IE 5111</td>
<td>Systems Engineering I (2.0 cr)</td>
</tr>
<tr>
<td>IE 5113</td>
<td>Systems Engineering II (4.0 cr)</td>
</tr>
<tr>
<td>IE 5511</td>
<td>Human Factors and Work Analysis (4.0 cr)</td>
</tr>
<tr>
<td>IE 5522</td>
<td>Quality Engineering and Reliability (4.0 cr)</td>
</tr>
<tr>
<td>IE 5541</td>
<td>Project Management (4.0 cr)</td>
</tr>
<tr>
<td>IE 5545</td>
<td>Decision Analysis (4.0 cr)</td>
</tr>
<tr>
<td>IE 5553</td>
<td>Simulation (4.0 cr)</td>
</tr>
<tr>
<td>KIN 5001</td>
<td>Foundations of Human Factors/Ergonomics (3.0 cr)</td>
</tr>
<tr>
<td>KIN 5643</td>
<td>Applied Motion Capture and Movement Analysis Technology (3.0 cr)</td>
</tr>
</tbody>
</table>
• MATH 5248 - Cryptology and Number Theory (4.0 cr)
• MATH 5445 - Mathematical Analysis of Biological Networks (4.0 cr)
• MATH 5447 - Theoretical Neuroscience (4.0 cr)
• MATH 5587 - Elementary Partial Differential Equations I (4.0 cr)
• MATH 5651 - Basic Theory of Probability and Statistics (4.0 cr)
• MATH 5652 - Introduction to Stochastic Processes (4.0 cr)
• MATH 8202 - General Algebra (3.0 cr)
• MATH 8253 - Algebraic Geometry (3.0 cr)
• MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
• MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
• MATS 8003 - Electronic Properties (3.0 cr)
• ME 5228 - Introduction to Finite Element Modeling, Analysis, and Design (4.0 cr)
• ME 5241 - Computer-Aided Engineering (4.0 cr)
• ME 5243 - Advanced Mechanism Design (4.0 cr)
• ME 5247 - Stress Analysis, Sensing, and Transducers (4.0 cr)
• ME 5281 - Analog and Digital Control (4.0 cr)
• ME 5286 - Robotics (4.0 cr)
• ME 5341 - Case Studies in Thermal Engineering and Design (4.0 cr)
• ME 5351 - Computational Heat Transfer (4.0 cr)
• ME 8254 - Fundamentals of Microelectromechanical Systems (MEMS) (4.0 cr)
• ME 8341 - Conduction (3.0 cr)
• ME 8342 - Convection (3.0 cr)
• ME 8343 - Radiation (3.0 cr)
• ME 8345 - Computational Heat Transfer and Fluid Flow (3.0 cr)
• MPHY 5170 - Basic Radiological Physics (3.0 cr)
• MPHY 5178 - Physical Principles of Magnetic Resonance Imaging (3.0 cr)
• MPHY 8147 - Advanced Physics of Magnetic Resonance Imaging (MRI) (3.0 cr)
• NSC 5202 - Theoretical Neuroscience: Systems and Information Processing (3.0 cr)
• NSCI 5300 - Biological Microscopy & Digital Imaging (3.0 cr)
• PHM 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
• PHYS 5081 - Introduction to Biopolymer Physics (3.0 cr)
• PHYS 5401 - Physiological Physics (4.0 cr)
• PSY 5036W - Computational Vision [WI] (3.0 cr)
• PUBH 6415 - Biostatistical Methods II (3.0 cr)
• PUBH 6450 - Biostatistics I (4.0 cr)
• PUBH 6451 - Biostatistics II (4.0 cr)
• PUBH 7440 - Introduction to Bayesian Analysis (3.0 cr)
• PUBH 7475 - Statistical Learning and Data Mining (3.0 cr)
• RSC 5135 - Advanced Biomechanics I: Kinematics (3.0 cr)
• RSC 5200 - Introduction to Neuromodulation (1.0 - 3.0 cr)
• RSC 5235 - Advanced Biomechanics II: Kinetics (3.0 cr)
• RSC 5841 - Applied Data Acquisition and Processing (3.0 cr)
• RSC 8135 - Human Kinematics (3.0 cr)
• RSC 8235 - Human Kinetics (3.0 cr)
• STAT 5021 - Statistical Analysis (4.0 cr)
• STAT 5101 - Theory of Statistics I (4.0 cr)
• STAT 5102 - Theory of Statistics II (4.0 cr)
• STAT 5302 - Applied Regression Analysis (4.0 cr)
• STAT 5303 - Designing Experiments (4.0 cr)

Free Electives
6 credits total, must include BMEn 8611. Additional courses may be approved by the director of graduate studies.

BMEN 8611 - Professional Skills and Ethics for Biomedical Engineers (2.0 cr)

Take 4 or more credit(s) from the following:
• BMEN 8402 - New Product Design and Business Development (4.0 cr)
• MILI 5589 - Medical Technology Evaluation and Market Research (2.0 cr)
• MOT 5001 - Technological Business Fundamentals (2.0 cr)
• MOT 5002 - Creating Technological Innovation (2.0 cr)
• MOT 5003 - Technological Business Planning Workshop (1.0 cr)
• PDES 5701 - Creativity, Idea Generation, and Innovation (3.0 cr)
• PDES 5702 - Concept Sketching and Rendering (3.0 cr)
• PDES 5704 - Computer-Aided Design Methods (3.0 cr)
• PHYS 5401 - Physiological Physics (4.0 cr)
• PSY 5036W - Computational Vision [WI] (3.0 cr)
• PUBH 6161 - Regulatory Toxicology (2.0 cr)
• PUBH 6414 - Biostatistical Literacy (3.0 cr)
• PUBH 7415 - Introduction to Clinical Trials (3.0 cr)
• RSC 5106 - Introduction to Rehabilitation Science (1.0 cr)

• Additional Core/Bio/Tech
Any course(s) from the BMEn Core, Biology Elective, and/or Technical Elective lists that are not being used toward another degree requirement.

• Coursework Relevant to Science and Technology
Max 3 credits in coursework relevant to science and technology (e.g., public policy, ethical/historical aspects, etc).
Take 0 - 3 credit(s) from the following:
• BTHX 5100 - Introduction to Clinical Ethics (3.0 cr)
• BTHX 5120 - Dying in Contemporary Medical Culture (2.0 cr)
• BTHX 5210 - Ethics of Human Subjects Research (3.0 cr)
• BTHX 5300 - Foundations of Bioethics (3.0 cr)
• BTHX 5325 - Biomedical Ethics (3.0 cr)
• BTHX 5650 - Disability Ethics (3.0 cr)
• BTHX 8120 - Dying in Contemporary Medical Culture (2.0 cr)
• MILI 6235 - Pharmaceutical Industry: Business and Policy (2.0 cr)
• MILI 6995 - Medical Industry Valuation Laboratory (2.0 cr)
• PHAR 5200 - Drugs and the US Health Care System (3.0 cr)

Math-/Statistics-Intensive
Included in the Core and/or Elective coursework must be at least 6 credits designated as Math-/Statistics-Intensive. These are not additional credits but will overlap with coursework already satisfying the BMEn Core, Technical Elective, and/or Free Elective requirements.
Take 6 or more credit(s) from the following:
• AEM 5451 - Optimal Estimation (3.0 cr)
• AEM 5501 - Continuum Mechanics (3.0 cr)
• AEM 5503 - Theory of Elasticity (3.0 cr)
• AEM 8511 - Advanced Topics in Continuum Mechanics (3.0 cr)
• BMEN 5111 - Biomedical Ultrasound (3.0 cr)
• BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
• BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
• BMEN 8201 - Advanced Tissue Mechanics (3.0 cr)
• BMEN 8381 - Bioheat and Mass Transfer (3.0 cr)
• BMEN 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
• BMEN 8501 - Dynamical Systems in Biology (3.0 cr)
• BMEN 8502 - Physiological Control Systems (3.0 cr)
• CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
• CHEN 8201 - Applied Math (3.0 cr)
• CHEN 8402 - Statistical Thermodynamics and Kinetics (3.0 cr)
• CHEN 8754 - Systems Analysis of Biological Processes (3.0 cr)
• CSCI 5521 - Introduction to Machine Learning (3.0 cr)
• CSCI 5525 - Machine Learning (3.0 cr)
• EE 5251 - Optimal Filtering and Estimation (3.0 cr)
• EE 5531 - Probability and Stochastic Processes (3.0 cr)
• EE 5542 - Adaptive Digital Signal Processing (3.0 cr)
• EE 5545 - Digital Signal Processing Design (3.0 cr)
• EE 5561 - Image Processing and Applications (3.0 cr)
• EE 5601 - Introduction to RF/Microwave Engineering (3.0 cr)
• EE 5621 - Physical Optics (3.0 cr)
• EE 8591 - Predictive Learning from Data (3.0 cr)
• IE 5522 - Quality Engineering and Reliability (4.0 cr)
• MATH 5248 - Cryptology and Number Theory (4.0 cr)
• MATH 5445 - Mathematical Analysis of Biological Networks (4.0 cr)
• MATH 5447 - Theoretical Neuroscience (4.0 cr)
• MATH 5587 - Elementary Partial Differential Equations I (4.0 cr)
• MATH 5651 - Basic Theory of Probability and Statistics (4.0 cr)
• MATH 5652 - Introduction to Stochastic Processes (4.0 cr)
• MATH 8202 - General Algebra (3.0 cr)
• MATH 8253 - Algebraic Geometry (3.0 cr)
• ME 5228 - Introduction to Finite Element Modeling, Analysis, and Design (4.0 cr)
• ME 5351 - Computational Heat Transfer (4.0 cr)
• ME 8341 - Conduction (3.0 cr)
• ME 8342 - Convection (3.0 cr)

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
• ME 8343 - Radiation (3.0 cr)
• ME 8345 - Computational Heat Transfer and Fluid Flow (3.0 cr)
• MPHY 8147 - Advanced Physics of Magnetic Resonance Imaging (MRI) (3.0 cr)
• PHM 8431 - Controlled Drug and Gene Delivery: Materials, Mechanisms, and Models (4.0 cr)
• PSY 5038W - Introduction to Neural Networks [WI] (3.0 cr)
• PUBH 6450 - Biostatistics I (4.0 cr)
• PUBH 6451 - Biostatistics II (4.0 cr)
• PUBH 7440 - Introduction to Bayesian Analysis (3.0 cr)
• PUBH 7475 - Statistical Learning and Data Mining (3.0 cr)
• STAT 5021 - Statistical Analysis (4.0 cr)
• STAT 5101 - Theory of Statistics I (4.0 cr)
• STAT 5102 - Theory of Statistics II (4.0 cr)
• STAT 5302 - Applied Regression Analysis (4.0 cr)
• STAT 5303 - Designing Experiments (4.0 cr)

**Thesis Credits**
Take 24 credits after passing preliminary oral exam

**BMEN 8888** - Thesis Credit: Doctoral (1.0 - 24.0 cr)
Twin Cities Campus
Chemical Engineering M.Ch.E.
Chemical Engineering & Materials Science
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Chemical Engineering and Materials Science, University of Minnesota, 151 Amundson Hall, 421 Washington Avenue SE, Minneapolis, MN 55455 (612-625-0382; fax 612-626-7246)
Email: cemsgrad@umn.edu
Website: http://www.cems.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Chemical Engineering

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Research activities in the Chemical Engineering and Materials Science (CEMS) Department focus on the development of renewable energy technologies, the solution of important medical and biological engineering challenges, the development of advanced materials, and the application of sophisticated mathematical and theoretical models.

Graduate courses offered cover core areas of chemical engineering (fluid mechanics, applied mathematics: linear and nonlinear analysis, transport, chemical thermodynamics, statistical thermodynamics and kinetics, and analysis of chemical reactors) and core areas of materials science (structure and symmetry of materials, thermodynamics and kinetics, electronic properties of materials, and mechanical properties of materials). In addition, several specialized topics are offered, including biochemical engineering, biological transport processes, food processing technology, colloids, principles of mass transfer in engineering and biological engineering, rheology, coating process fundamentals, process control, finite elements methods of computer-aided analysis, ceramics, polymers, materials design and performance, materials processing, corrosion, introduction to polymer chemistry, polymer laboratory, contact and fracture properties of materials, electron microscopy, thin films and interfaces, composites, electrochemical engineering, physical chemistry of polymers, solid state reaction kinetics, electronic structure of materials, electronic properties and applications of organic materials, electronic ceramics, dislocations and interfaces, epitaxial thin film growth, and science of porous media.

The master of chemical engineering (M.Ch.E.), also known as the professional master's, is designed for working professionals who are interested in obtaining a master's degree part-time. This degree requires a design project. Part-time students may also choose the M.S.Ch.E. Plan C, which is coursework only.

The CEMS department focuses on the PhD, and does not generally admit students directly to the M.S.Ch.E. Plan A degree, which is a thesis-based master's and is intended for current graduate students who choose not to seek a PhD.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
A bachelor's degree in chemical engineering or other related field.

Other requirements to be completed before admission:
This professional master of engineering degree is designed for employees of local industries who wish to pursue their studies part-time. No financial support is available. Applicants should contact the program before applying for admission.

Special Application Requirements:
Applicants must submit scores from the General Test of the GRE; three letters of recommendation from persons familiar with their scholarship and research potential; a complete set of official transcripts; and a clearly written statement of career interests, goals, and objectives. International students are required to provide TOEFL results.

Applications are accepted for fall semester only. December 15 is the application deadline; late applications are considered if space is
International applicants must submit score(s) from one of the following tests:

- **TOEFL**
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 560
- **IELTS**
  - Total Score: 6.5
- **MELAB**
  - Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

**Program Requirements**

**Plan A**: Plan A requires 12 to 14 major credits, 6 to 8 credits outside the major, and 10 thesis credits. The final exam is oral.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 2.80 is required for students to remain in good standing.

In addition to the coursework, MChE students are required to complete a design project. The work-related MChE design project consists of an in-depth study of an engineering design. It need not represent a publishable research project. While the amount of work should be the same as for a master's thesis, the project can contain elements that the thesis would not, such as economic considerations, design consultation, and social relevance.

**Core Courses (12 Credits)**
Take at least 12 credits from the following, in consultation with the advisor.

- **CHEN 8101** - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
- **CHEN 8201** - Applied Math (3.0 cr)
- **CHEN 8301** - Physical Rate Processes I: Transport (3.0 cr)
- **CHEN 8401** - Physical and Chemical Thermodynamics (3.0 cr)
- **CHEN 8402** - Statistical Thermodynamics and Kinetics (3.0 cr)
- **CHEN 8501** - Chemical Rate Processes: Analysis of Chemical Reactors (3.0 cr)

**Thesis Credits**
10 thesis credits are required for the design project.

**Electives**
Select remaining coursework, in consultation with the advisor, to complete the 20 course credits required.

- **AEM 5321** - Modern Feedback Control (3.0 cr)
- **AEM 5501** - Continuum Mechanics (3.0 cr)
- **AEM 5503** - Theory of Elasticity (3.0 cr)
- **AEM 8201** - Fluid Mechanics I (3.0 cr)
- **AEM 8202** - Fluid Mechanics II (3.0 cr)
- **AEM 8203** - Fluid Mechanics III (3.0 cr)
- **AEM 8251** - Finite-Volume Methods in Computational Fluid Dynamics (3.0 cr)
- **AEM 8421** - Robust Multivariable Control Design (3.0 cr)
- **AEM 8541** - Mechanics of Crystalline Solids (3.0 cr)
- **BIOC 4332** - Biochemistry II: Molecular Mechanisms of Signal Transduction and Gene Expression (4.0 cr)
- **BIOC 5528** - Spectroscopy and Kinetics (4.0 cr)
- **BIOC 6021** - Biochemistry (3.0 cr)
- **BIOC 8002** - Molecular Biology and Regulation of Biological Processes (3.0 cr)
- **BMEN 5001** - Advanced Biomaterials (3.0 cr)
MATS 4223W - Polymer Laboratory [WI] (2.0 cr)
MATS 5517 - Electron Microscopy (3.0 cr)
MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
MATS 8003 - Electronic Properties (3.0 cr)
MATS 8004 - Mechanical Properties (3.0 cr)
MATS 8211 - Physical Chemistry of Polymers (4.0 cr)
MATS 8221 - Synthetic Polymer Chemistry (4.0 cr)
MATS 8301 - Physical Rate Processes I: Transport (3.0 cr)
ME 5113 - Aerosol/Particle Engineering (4.0 cr)
ME 5446 - Introduction to Combustion (4.0 cr)
ME 8341 - Conduction (3.0 cr)
ME 8390 - Advanced Topics in the Thermal Sciences (1.0 - 3.0 cr)
MICA 8002 - Structure, Function, and Genetics of Bacteria and Viruses (4.0 cr)
STAT 5021 - Statistical Analysis (4.0 cr)

Special Topics Electives
The following electives are topics courses. Only the approved topic titles below may be used.
AEM 8511 Advanced Topics in Continuum Mechanics - Problems in Materials Science
CEGE 5180 Special Topics - Membrane Science and Technology
EE 5940 Special Topics - Infrared Technology and Environmental Sensing
Math 8450 Topics in Numerical Analysis - Applications of Continuum Mechanics in Biology
Mats 8995 Special Topics - Scattering from Soft Materials
Twin Cities Campus
Chemical Engineering M.S.Ch.E.
Chemical Engineering & Materials Science
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Chemical Engineering and Materials Science, University of Minnesota, 151 Amundson Hall, 421 Washington Ave SE, Minneapolis, MN 55455 (612-625-0382; fax: 612-626-7246)
Email: cemsgrad@umn.edu
Website: http://www.cems.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program requires summer semesters for timely completion.
- Degree: Master of Science in Chemical Engineering

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The CEMS Department offers two types of master's degrees: the MSChE (Plan A or C) and the MChE degree, also known as the professional master's. The MSChE Plan A degree is a thesis-based master's and is generally reserved only for current graduate students who choose not to seek a PhD. Working professionals who are interested in obtaining a master's degree part time should follow the requirements for the MChE degree, which requires a design project, or the MSChE Plan C, which is coursework only.

Research activities in CEMS focus on the development of renewable energy technologies, the solution of important medical and biological engineering challenges, the development of advanced materials, and the application of sophisticated mathematical and theoretical models.

Graduate courses offered cover core areas of chemical engineering (fluid mechanics, applied mathematics: linear and nonlinear analysis, transport, chemical thermodynamics, statistical thermodynamics and kinetics, and analysis of chemical reactors) and core areas of materials science (structure and symmetry of materials, thermodynamics and kinetics, electronic properties of materials, and mechanical properties of materials). In addition, several specialized topics are offered, including biochemical engineering, biological transport processes, food processing technology, colloids, principles of mass transfer in engineering and biological engineering, rheology, coating process fundamentals, process control, finite elements methods of computer-aided analysis, ceramics, polymers, materials design and performance, materials processing, corrosion, introduction to polymer chemistry, polymer laboratory, contact and fracture properties of materials, electron microscopy, thin films and interfaces, composites, electrochemical engineering, physical chemistry of polymers, solid state reaction kinetics, electronic structure of materials, electronic properties and applications of organic materials, electronic ceramics, dislocations and interfaces, epitaxial thin film growth, and science of porous media.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
A bachelor's degree in chemical engineering or other related field.

Other requirements to be completed before admission:
With the exception of the professional master's degree (the MChE) and the MSChE Plan C, the CEMS Department focuses on the PhD and does not generally admit students directly to the MSChE Plan A degree.

Special Application Requirements:
Applicants must submit scores from the General Test of the GRE; three letters of recommendation from persons familiar with their scholarship and research potential; a complete set of official transcripts; and a clearly written statement of career interests, goals, and objectives. International students are required to provide TOEFL results.

Applications are accepted for fall semester only. December 15 is the application deadline; late applications are considered if space is available. More information is available at http://www.cems.umn.edu/graduate/admissions

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
Applicants must submit their test score(s) from the following:

- GRE

International applicants must submit score(s) from one of the following tests:

- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 560
- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

**Plan A:** Plan A requires 12 to 14 major credits, 6 to 8 credits outside the major, and 10 thesis credits. The final exam is written and oral.

**Plan C:** Plan C requires 12 to 18 major credits and 12 to 18 credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 2.80 is required for students to remain in good standing.

**Core Courses**

Take 4 or more course(s) totaling 12 or more credit(s) from the following:

- CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
- CHEN 8201 - Applied Math (3.0 cr)
- CHEN 8301 - Physical Rate Processes I: Transport (3.0 cr)
- CHEN 8401 - Physical and Chemical Thermodynamics (3.0 cr)
- CHEN 8402 - Statistical Thermodynamics and Kinetics (3.0 cr)
- CHEN 8501 - Chemical Rate Processes: Analysis of Chemical Reactors (3.0 cr)

**Plan A**

Plan A requires 12 credits in the major, 6 credits outside the major, and 10 thesis credits. The remaining course credits may be taken in the major or in any supporting field.

**CHEN 8777** - Thesis Credits: Master's (1.0 - 18.0 cr)

**Plan C**

Plan C requires 12 credits in the major and a minimum of 12 credits outside the major. The remaining 6 credits may be taken in the major or in any supporting field.

**Electives**

The remaining credits may be chosen from the following list or consult with advisor for further options.

- AEM 5321 - Modern Feedback Control (3.0 cr)
- AEM 5501 - Continuum Mechanics (3.0 cr)
- AEM 5503 - Theory of Elasticity (3.0 cr)
- AEM 8201 - Fluid Mechanics I (3.0 cr)
- AEM 8202 - Fluid Mechanics II (3.0 cr)
- AEM 8203 - Fluid Mechanics III (3.0 cr)
- AEM 8251 - Finite-Volume Methods in Computational Fluid Dynamics (3.0 cr)
- AEM 8421 - Robust Multivariable Control Design (3.0 cr)
- AEM 8541 - Mechanics of Crystalline Solids (3.0 cr)
- BIOC 4332 - Biochemistry II: Molecular Mechanisms of Signal Transduction and Gene Expression (4.0 cr)
- BIOC 5528 - Spectroscopy and Kinetics (4.0 cr)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOC 6021</td>
<td>Biochemistry</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BIOC 8002</td>
<td>Molecular Biology and Regulation of Biological Processes</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BMEN 5001</td>
<td>Advanced Biomaterials</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BMEN 5201</td>
<td>Advanced Biomechanics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BMEN 5311</td>
<td>Advanced Biomedical Transport Processes</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BMEN 5351</td>
<td>Cell Engineering</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BMEN 5501</td>
<td>Biology for Biomedical Engineers</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BMEN 8511</td>
<td>Systems and Synthetic Biology</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CEGE 8022</td>
<td>Numerical Methods for Free and Moving Boundary Problems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CEGE 8401</td>
<td>Fundamentals of Finite Element Method</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CEGE 8402</td>
<td>Nonlinear Finite Element Analysis</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CEGE 8501</td>
<td>Environmental Fluid Mechanics I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CEGE 8502</td>
<td>Environmental Fluid Mechanics II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CEGE 8504</td>
<td>Theory of Unit Operations</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CEGE 8505</td>
<td>Biological Processes</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEM 5210</td>
<td>Materials Characterization</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8011</td>
<td>Mechanisms of Chemical Reactions</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8021</td>
<td>Computational Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8151</td>
<td>Analytical Separations and Chemical Equilibria</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8152</td>
<td>Analytical Spectroscopy</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8201</td>
<td>Materials Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8211</td>
<td>Physical Polymer Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8221</td>
<td>Synthetic Polymer Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8361</td>
<td>Interpretation of Organic Spectra</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8551</td>
<td>Quantum Mechanics I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8561</td>
<td>Thermodynamics, Statistical Mechanics, and Reaction Dynamics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8562</td>
<td>Thermodynamics, Statistical Mechanics, and Reaction Dynamics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEN 4214</td>
<td>Polymers</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 5751</td>
<td>Biochemical Engineering</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 5753</td>
<td>Advanced Biomedical Transport Processes</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 5771</td>
<td>Colloids and Dispersions</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8101</td>
<td>Fluid Mechanics I: Change, Deformation, Equations of Flow</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8102</td>
<td>Principles and Applications of Rheology</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>CHEN 8104</td>
<td>Coating Process Fundamentals</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>CHEN 8201</td>
<td>Applied Math</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8221</td>
<td>Synthetic Polymer Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEN 8301</td>
<td>Physical Rate Processes I: Transport</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8401</td>
<td>Physical and Chemical Thermodynamics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8402</td>
<td>Statistical Thermodynamics and Kinetics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8501</td>
<td>Chemical Rate Processes: Analysis of Chemical Reactors</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8754</td>
<td>Systems Analysis of Biological Processes</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5302</td>
<td>Analysis of Numerical Algorithms</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5304</td>
<td>Computational Aspects of Matrix Theory</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 8363</td>
<td>Numerical Linear Algebra in Data Exploration</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5163</td>
<td>Semiconductor Properties and Devices I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5164</td>
<td>Semiconductor Properties and Devices II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5181</td>
<td>Micro and Nanotechnology by Self Assembly</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5231</td>
<td>Linear Systems and Optimal Control</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5239</td>
<td>Introduction to Nonlinear Optimization</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5657</td>
<td>Physical Principles of Thin Film Technology</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 8161</td>
<td>Physics of Semiconductors</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>GCD 4034</td>
<td>Molecular Genetics and Genomics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>GCD 8151</td>
<td>Cellular Biochemistry and Cell Biology</td>
<td>2.0 - 4.0 cr</td>
</tr>
<tr>
<td>GCD 8161</td>
<td>Advanced Cell Biology and Development</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 4428</td>
<td>Mathematical Modeling</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4512</td>
<td>Differential Equations with Applications</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 5485</td>
<td>Introduction to Numerical Methods I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5486</td>
<td>Introduction To Numerical Methods II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5525</td>
<td>Introduction to Ordinary Differential Equations</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5535</td>
<td>Dynamical Systems and Chaos</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5587</td>
<td>Elementary Partial Differential Equations I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5588</td>
<td>Elementary Partial Differential Equations II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5651</td>
<td>Basic Theory of Probability and Statistics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5652</td>
<td>Introduction to Stochastic Processes</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 8441</td>
<td>Numerical Analysis and Scientific Computing</td>
<td>3.0 cr</td>
</tr>
</tbody>
</table>
MATH 8442 - Numerical Analysis and Scientific Computing (3.0 cr)
MATS 4212 - Ceramics (3.0 cr)
MATS 4214 - Polymers (3.0 cr)
MATS 4223W - Polymer Laboratory [WI] (2.0 cr)
MATS 5517 - Electron Microscopy (3.0 cr)
MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
MATS 8003 - Electronic Properties (3.0 cr)
MATS 8004 - Mechanical Properties (3.0 cr)
MATS 8211 - Physical Chemistry of Polymers (4.0 cr)
MATS 8221 - Synthetic Polymer Chemistry (4.0 cr)
MATS 8301 - Physical Rate Processes I: Transport (3.0 cr)
ME 5113 - Aerosol/Particle Engineering (4.0 cr)
ME 5446 - Introduction to Combustion (4.0 cr)
ME 8341 - Conduction (3.0 cr)
ME 8390 - Advanced Topics in the Thermal Sciences (1.0 - 3.0 cr)
MICA 8002 - Structure, Function, and Genetics of Bacteria and Viruses (4.0 cr)
STAT 5021 - Statistical Analysis (4.0 cr)

**Special Topics Electives**
The following electives are topics courses. Only the approved topic titles below may be used.
AEM 8511 Advanced Topics in Continuum Mechanics - Problems in Materials Science
CEGE 5180 Special Topics - Membrane Science and Technology
EE 5940 Special Topics - Infrared Technology and Environmental Sensing
Math 8450 Topics in Numerical Analysis - Applications of Continuum Mechanics in Biology
Mats 8995 Special Topics - Scattering from Soft Materials
Twin Cities Campus
Chemical Engineering Minor
Chemical Engineering & Materials Science
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Chemical Engineering and Materials Science, University of Minnesota, 151 Amundson Hall, 421 Washington Ave SE, Minneapolis, MN 55455 (612-625-0382; fax: 612-626-7246)
Email: cemsgrad@umn.edu
Website: http://www.cems.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Research activities in the Chemical Engineering and Materials Science (CEMS) Department focus on the development of renewable energy technologies, the solution of important medical and biological engineering challenges, the development of advanced materials, and the application of sophisticated mathematical and theoretical models.

Graduate courses offered cover core areas of chemical engineering (fluid mechanics, applied mathematics: linear and nonlinear analysis, transport, chemical thermodynamics, statistical thermodynamics and kinetics, and analysis of chemical reactors). In addition, several specialized topics are offered, including biochemical engineering, biological transport processes, food processing technology, colloids, principles of mass transfer in engineering and biological engineering, rheology, coating process fundamentals, process control, finite elements methods of computer-aided analysis, ceramics, polymers, materials design and performance, materials processing, corrosion, introduction to polymer chemistry, polymer laboratory, contact and fracture properties of materials, electron microscopy, thin films and interfaces, composites, electrochemical engineering, physical chemistry of polymers, solid state reaction kinetics, electronic structure of materials, electronic properties and applications of organic materials, electronic ceramics, dislocations and interfaces, epitaxial thin film growth, and science of porous media.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

Minor programs must be approved by the director of Graduate Studies in Chemical Engineering.

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Masters
Core Courses
Take 2 or more course(s) totaling 6 or more credit(s) from the following:

- CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
- CHEN 8201 - Applied Math (3.0 cr)
- CHEN 8301 - Physical Rate Processes I: Transport (3.0 cr)
- CHEN 8401 - Physical and Chemical Thermodynamics (3.0 cr)
- CHEN 8402 - Statistical Thermodynamics and Kinetics (3.0 cr)
- CHEN 8501 - Chemical Rate Processes: Analysis of Chemical Reactors (3.0 cr)

Doctoral Core Courses

Take 4 or more course(s) totaling 12 or more credit(s) from the following:

- CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
- CHEN 8201 - Applied Math (3.0 cr)
- CHEN 8301 - Physical Rate Processes I: Transport (3.0 cr)
- CHEN 8401 - Physical and Chemical Thermodynamics (3.0 cr)
- CHEN 8402 - Statistical Thermodynamics and Kinetics (3.0 cr)
- CHEN 8501 - Chemical Rate Processes: Analysis of Chemical Reactors (3.0 cr)
Twin Cities Campus
Chemical Engineering Ph.D.
Chemical Engineering & Materials Science
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Chemical Engineering and Materials Science, University of Minnesota, 151 Amundson Hall, 421 Washington Avenue SE, Minneapolis, MN 55455 (612-625-0382; fax: 612-626-7246)
Email: cemsgrad@umn.edu
Website: http://www.cems.umn.edu

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 57
- This program requires summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Research activities in the Chemical Engineering and Materials Science (CEMS) Department focus on the development of renewable energy technologies, the solution of important medical and biological engineering challenges, the development of advanced materials, and the application of sophisticated mathematical and theoretical models.

Graduate courses offered cover core areas of chemical engineering (fluid mechanics, applied mathematics: linear and nonlinear analysis, transport, chemical thermodynamics, statistical thermodynamics and kinetics, and analysis of chemical reactors) and core areas of materials science (structure and symmetry of materials, thermodynamics and kinetics, electronic properties of materials, and mechanical properties of materials). In addition, several specialized topics are offered, including biochemical engineering, biological transport processes, food processing technology, colloids, principles of mass transfer in engineering and biological engineering, rheology, coating process fundamentals, process control, finite elements methods of computer-aided analysis, ceramics, polymers, materials design and performance, materials processing, corrosion, introduction to polymer chemistry, polymer laboratory, contact and fracture properties of materials, electron microscopy, thin films and interfaces, composites, electrochemical engineering, physical chemistry of polymers, solid state reaction kinetics, electronic structure of materials, electronic properties and applications of organic materials, electronic ceramics, dislocations and interfaces, epitaxial thin film growth, and science of porous media.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
A bachelor's degree in chemical engineering or related field.

Other requirements to be completed before admission:
Applicants must submit scores from the General Test of the GRE; three letters of recommendation from persons familiar with their scholarship and research potential; a complete set of official transcripts; and a clearly written statement of career interests, goals, and objectives. International students are required to provide TOEFL results.

Special Application Requirements:
Applications are accepted for fall semester only. Submission of all application materials by December 15 is strongly encouraged to ensure priority consideration for fellowships and assistantships; late applications are considered if space is available. More information is available at http://www.cems.umn.edu/graduate/admissions

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
- Internet Based - Reading Score: 19
- Paper Based - Total Score: 560

- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the [General Information](#) section of the catalog website.

**Program Requirements**

21 credits are required in the major.
12 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

The PhD requires 33 course credits and 24 thesis credits. The course credits must include 12 credits in CHEN core courses and a minimum of 12 credits outside the major. The remaining 9 credits may be taken in the major or in any supporting field.

Students must attend, but not enroll in, the departmental seminar for six semesters. Informal attendance will be done within the department.

**Core Courses**

Take 4 or more course(s) totaling 12 or more credit(s) from the following:

- CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
- CHEN 8201 - Applied Math (3.0 cr)
- CHEN 8301 - Physical Rate Processes I: Transport (3.0 cr)
- CHEN 8401 - Physical and Chemical Thermodynamics (3.0 cr)
- CHEN 8402 - Statistical Thermodynamics and Kinetics (3.0 cr)
- CHEN 8501 - Chemical Rate Processes: Analysis of Chemical Reactors (3.0 cr)

**Thesis Credits**

Take 24 credits after passing preliminary oral exam.

CHEN 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)

**Electives**

The remaining credits may be chosen from this list or consult with advisor for further options.

AEM 5321 - Modern Feedback Control (3.0 cr)
AEM 5501 - Continuum Mechanics (3.0 cr)
AEM 5503 - Theory of Elasticity (3.0 cr)
AEM 8201 - Fluid Mechanics I (3.0 cr)
AEM 8202 - Fluid Mechanics II (3.0 cr)
AEM 8203 - Fluid Mechanics III (3.0 cr)
AEM 8251 - Finite-Volume Methods in Computational Fluid Dynamics (3.0 cr)
AEM 8421 - Robust Multivariable Control Design (3.0 cr)
AEM 8541 - Mechanics of Crystalline Solids (3.0 cr)
BIOC 4332 - Biochemistry II: Molecular Mechanisms of Signal Transduction and Gene Expression (4.0 cr)
BIOC 5528 - Spectroscopy and Kinetics (4.0 cr)
BIOC 6021 - Biochemistry (3.0 cr)
BIOC 8002 - Molecular Biology and Regulation of Biological Processes (3.0 cr)
BMEN 5001 - Advanced Biomaterials (3.0 cr)
BMEN 5201 - Advanced Biomechanics (3.0 cr)
BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
BMEN 5351 - Cell Engineering (3.0 cr)
BMEN 5501 - Biology for Biomedical Engineers (3.0 cr)
BMEN 8511 - Systems and Synthetic Biology (3.0 cr)
CEGE 8022 - Numerical Methods for Free and Moving Boundary Problems (3.0 cr)
CEGE 8401 - Fundamentals of Finite Element Method (3.0 cr)
CEGE 8402 - Nonlinear Finite Element Analysis (3.0 cr)
CEGE 8501 - Environmental Fluid Mechanics I (4.0 cr)
CEGE 8502 - Environmental Fluid Mechanics II (4.0 cr)
CEGE 8504 - Theory of Unit Operations (4.0 cr)
CEGE 8505 - Biological Processes (3.0 cr)
CHEM 5210 - Materials Characterization (4.0 cr)
CHEM 8011 - Mechanisms of Chemical Reactions (4.0 cr)
CHEM 8021 - Computational Chemistry (4.0 cr)
CHEM 8151 - Analytical Separations and Chemical Equilibria (4.0 cr)
CHEM 8152 - Analytical Spectroscopy (4.0 cr)
CHEM 8201 - Materials Chemistry (4.0 cr)
CHEM 8211 - Physical Polymer Chemistry (4.0 cr)
CHEM 8221 - Synthetic Polymer Chemistry (4.0 cr)
CHEM 8361 - Interpretation of Organic Spectra (4.0 cr)
CHEM 8551 - Quantum Mechanics I (4.0 cr)
CHEM 8561 - Thermodynamics, Statistical Mechanics, and Reaction Dynamics I (4.0 cr)
CHEM 8562 - Thermodynamics, Statistical Mechanics, and Reaction Dynamics II (4.0 cr)
CHEN 4214 - Polymers (3.0 cr)
CHEN 5751 - Biochemical Engineering (3.0 cr)
CHEN 5753 - Advanced Biomedical Transport Processes (3.0 cr)
CHEN 5771 - Colloids and Dispersions (3.0 cr)
CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
CHEN 8102 - Principles and Applications of Rheology (2.0 cr)
CHEN 8104 - Coating Process Fundamentals (2.0 cr)
CHEN 8201 - Applied Math (3.0 cr)
CHEN 8221 - Synthetic Polymer Chemistry (4.0 cr)
CHEN 8301 - Physical Rate Processes I: Transport (3.0 cr)
CHEN 8401 - Physical and Chemical Thermodynamics (3.0 cr)
CHEN 8402 - Statistical Thermodynamics and Kinetics (3.0 cr)
CHEN 8501 - Chemical Rate Processes: Analysis of Chemical Reactors (3.0 cr)
CHEN 8754 - Systems Analysis of Biological Processes (3.0 cr)
CSCI 5302 - Analysis of Numerical Algorithms (3.0 cr)
CSCI 5304 - Computational Aspects of Matrix Theory (3.0 cr)
CSCI 8363 - Numerical Linear Algebra in Data Exploration (3.0 cr)
EE 1633 - Semiconductor Properties and Devices I (3.0 cr)
EE 5164 - Semiconductor Properties and Devices II (3.0 cr)
EE 5181 - Micro and Nanotechnology by Self Assembly (3.0 cr)
EE 5231 - Linear Systems and Optimal Control (3.0 cr)
EE 5239 - Introduction to Nonlinear Optimization (3.0 cr)
EE 5657 - Physical Principles of Thin Film Technology (4.0 cr)
EE 8161 - Physics of Semiconductors (3.0 cr)
GCD 4034 - Molecular Genetics and Genomics (3.0 cr)
GCD 8151 - Cellular Biochemistry and Cell Biology (2.0 - 4.0 cr)
GCD 8161 - Advanced Cell Biology and Development (3.0 cr)
MATH 4428 - Mathematical Modeling (4.0 cr)
MATH 4512 - Differential Equations with Applications (3.0 cr)
MATH 5485 - Introduction to Numerical Methods I (4.0 cr)
MATH 5486 - Introduction To Numerical Methods II (4.0 cr)
MATH 5525 - Introduction to Ordinary Differential Equations (4.0 cr)
MATH 5535 - Dynamical Systems and Chaos (4.0 cr)
MATH 5587 - Elementary Partial Differential Equations I (4.0 cr)
MATH 5588 - Elementary Partial Differential Equations II (4.0 cr)
MATH 5651 - Basic Theory of Probability and Statistics (4.0 cr)
MATH 5652 - Introduction to Stochastic Processes (4.0 cr)
MATH 6441 - Numerical Analysis and Scientific Computing (3.0 cr)
MATH 6442 - Numerical Analysis and Scientific Computing (3.0 cr)
MATS 4212 - Ceramics (3.0 cr)
MATS 4214 - Polymers (3.0 cr)
MATS 4223W - Polymer Laboratory [WI] (2.0 cr)
MATS 5517 - Electron Microscopy (3.0 cr)
MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
MATS 8003 - Electronic Properties (3.0 cr)
MATS 8004 - Mechanical Properties (3.0 cr)
MATS 8211 - Physical Chemistry of Polymers (4.0 cr)
MATS 8221 - Synthetic Polymer Chemistry (4.0 cr)
MATS 8301 - Physical Rate Processes I: Transport (3.0 cr)
ME 5113 - Aerosol/Particle Engineering (4.0 cr)
ME 5446 - Introduction to Combustion (4.0 cr)
ME 8341 - Conduction (3.0 cr)
ME 8390 - Advanced Topics in the Thermal Sciences (1.0 - 3.0 cr)
MICA 8002 - Structure, Function, and Genetics of Bacteria and Viruses (4.0 cr)
STAT 5021 - Statistical Analysis (4.0 cr)

Special Topics Electives
The following electives are topics courses. Only the approved topic titles below may be used.
AEM 8511 Advanced Topics in Continuum Mechanics - Problems in Materials Science
CEGE 5180 Special Topics - Membrane Science and Technology
EE 5940 Special Topics - Infrared Technology and Environmental Sensing
Math 8450 Topics in Numerical Analysis - Applications of Continuum Mechanics in Biology
Mats 8995 Special Topics - Scattering from Soft Materials
Twin Cities Campus
Chemical Physics M.S.
Chemistry
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Chemical Physics Program, University of Minnesota, 137 Smith Hall, 207 Pleasant St SE, Minneapolis, MN 55455 (612-626-7444; fax: 612-626-7541)
Email: chmapply@umn.edu
Website: http://chem.umn.edu/academics/graduate/chemical-physics

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program requires summer semesters for timely completion.
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Chemical physics focuses on research areas where the techniques of chemistry and physics are combined for the study of atoms and molecules; their interactions in gases, liquids, and solids; and the detailed structure and dynamics of material changes. Areas of research and specialization include spectroscopy, optical properties, laser applications, molecular collisions, chemical dynamics, quantum mechanics, computational chemistry, statistical mechanics, thermodynamics, low-temperature behavior, polymers and macromolecules, surface science, biochemistry, and biochemical and heterogeneous catalysis.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
An undergraduate degree in chemistry, physics or a related field is required for admission. The preferred minimum undergraduate GPA for admittance to the program is 3.2.

Other requirements to be completed before admission:
Prospective graduate students should have adequate undergraduate preparation in chemistry, physics and mathematics.

Three letters of recommendation and scores from the GRE general test are required for all applications. In addition, international applicants are expected to provide scores of at least 587 (paper), 240 (computer), or 95 (Internet) on the TOEFL.

A Subject GRE score is not required but if available will help the admission committee to make better decisions, in particular in cases where undergraduate transcripts are more difficult to evaluate (which is especially true for international applicants, who are strongly encouraged to submit the GRE subject score). The Subject GRE can be taken in Chemistry, Physics, or a related discipline.

Special Application Requirements:
Applications for fall semester must be completed by December 15 in order to be considered for financial support. Applications received after December 15 will be reviewed on a space available basis. The department prefers to admit for fall semester and will only consider spring admission under extenuating circumstances. More application information is available at www.chem.umn.edu/chemphys

Applicants must submit their test score(s) from the following:
• GRE

International applicants must submit score(s) from one of the following tests:
• TOEFL
  - Internet Based - Total Score: 95
  - Internet Based - Speaking Score: 23
• IELTS
  - Total Score: 7
• MELAB

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
- Final score: 83

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

**Plan A:** Plan A requires 20 major credits, up to null credits outside the major, and 10 thesis credits. The final exam is oral.

**Plan B:** Plan B requires 30 major credits and up to null credits outside the major. The final exam is written. A capstone project is required.

**Capstone Project:** Each Plan B project should involve a combined total of approximately 160 hours (the equivalent of four full-time weeks) of library research, reading, and/or writing resulting in the preparation of a significant written document. Students who plan to work on Plan B projects independent of the Preliminary Examination should present a plan, after consultation with the chosen instructor for the Plan B project, outlining the number and content of their projects to the director of graduate studies. Projects should be completed to the satisfaction of the instructor; the final grade is determined by the instructor.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 2.8 is required for students to remain in good standing.

Students are expected to pass a proficiency exam in physical chemistry during their first academic year in residence.

The MS degree requires a minimum of 30 credits and is offered under Plan A (thesis) and Plan B (project). The course credits must include at least 6 credits each in chemistry (CHEM) and physics (PHYS) or at least 3 credits each in quantum mechanics, thermodynamics, and statistical mechanics.

All first-year students must register for CHPH 8601 during both fall and spring semesters and for CHEM 8066 during the spring semester of their first year in residence.

**Required Courses**

Any CHPH, CHEM, and PHYS courses at the 5xxx or 8xxx level may be used to satisfy degree requirements. Up to 8 credits in 4xxx-level courses may be used with approval from the director of graduate studies.

Students may count one credit each of the following towards the degree.

*CHEM 8066 - Professional Conduct of Chemical Research (1.0 cr)*
*CHPH 8601 - Seminar: Modern Problems in Chemical Physics (1.0 cr)*

**Plan A**

Plan A requires 20 course credits and 10 thesis credits.

*CHPH 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)*

**Plan B**

Plan B requires 30 credits of coursework, including 8 credits in the two Plan B project courses.

*CHPH 8081 - M.S. Plan B Project I (4.0 cr)*
*CHPH 8082 - M.S. Plan B Project II (4.0 cr)*
Twin Cities Campus
Chemical Physics Minor
Chemistry
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Chemical Physics Program, University of Minnesota, 137 Smith Hall, 207 Pleasant Street SE, Minneapolis, MN 55455 (612-626-7444; fax: 612-626-7541)
Email: chmapply@umn.edu
Website: http://chem.umn.edu/academics/graduate/chemical-physics

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Chemical physics focuses on research areas where the techniques of chemistry and physics are combined for the study of atoms and molecules; their interactions in gases, liquids, and solids, and the detailed structure and dynamics of material changes. Areas of research and specialization include spectroscopy, optical properties, laser applications, molecular collisions, chemical dynamics, quantum mechanics, computational chemistry, statistical mechanics, thermodynamics, low-temperature behavior, polymers and macromolecules, surface science, biochemistry, and biochemical and heterogeneous catalysis.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

Minor field coursework, determined by the chemical physics director of graduate studies, student, and advisor, may include any 5xxx- or 8xxx-level CPHH, CHEM, or PHYS courses taken on the A-F grading basis.

Program Sub-plans
Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

Masters
The master's minor requires a minimum of 3 credits each in chemistry (CHEM) and physics (PHYS).

Doctoral
The doctoral minor requires a minimum of 6 credits each in chemistry (CHEM) and physics (PHYS).
**Twin Cities Campus**

**Chemical Physics Ph.D.**

**Chemistry**

**College of Science and Engineering**

Link to a list of faculty for this program.

**Contact Information:**
Chemical Physics Program, University of Minnesota, 137 Smith Hall, 207 Pleasant St SE, Minneapolis, MN 55455 (612-626-7444; fax: 612-626-7541)
Email: chmapply@umn.edu
Website: http://chem.umn.edu/academics/graduate/chemical-physics

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 48
- This program requires summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Chemical physics focuses on research areas where the techniques of chemistry and physics are combined for the study of atoms and molecules; their interactions in gases, liquids, and solids; and the detailed structure and dynamics of material changes. Areas of research and specialization include spectroscopy, optical properties, laser applications, molecular collisions, chemical dynamics, quantum mechanics, computational chemistry, statistical mechanics, thermodynamics, low-temperature behavior, polymers and macromolecules, surface science, biochemistry, and biochemical and heterogeneous catalysis.

**Program Delivery**
This program is available:
- via classroom (the majority of instruction is face-to-face)

**Prerequisites for Admission**
An undergraduate degree in chemistry, physics, or a related field is required for admission. The preferred minimum undergraduate GPA for admittance to the program is 3.2

Other requirements to be completed before admission:
Prospective graduate students should have adequate undergraduate preparation in chemistry, physics and mathematics.

Three letters of recommendation and scores from the GRE general test are required for all applications. In addition, international applicants are expected to provide scores of at least 587 (paper), 240 (computer), or 95 (Internet) on the TOEFL.

A Subject GRE score is not required but if available will help the admission committee to make better decisions, in particular in cases where undergraduate transcripts are more difficult to evaluate (which is especially true for international applicants, who are strongly encouraged to submit the GRE subject score). The Subject GRE can be taken in chemistry, physics, or a related discipline.

**Special Application Requirements:**
Applications for fall semester must be completed by December 15 in order to be considered for financial support. Applications received after December 15 will be reviewed on a space available basis. The program prefers to admit for fall semester and will only consider spring admission under extenuating circumstances. More application information is available at www.chem.umn.edu/chemphys

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 95
  - Internet Based - Speaking Score: 23
- IELTS
  - Total Score: 7
- MELAB
Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
24 credits are required in the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

Students are expected to pass a proficiency exam in physical chemistry during their first academic year in residence.

Each first-year chemical physics student will choose a program of study in consultation with his or her TMC (three-member committee).

The 24 course credits required must include either:

(a) At least 5 credits in chemistry (CHEM) and at least 5 credits in physics (PHYS), or
(b) At least 16 credits in chemistry and/or physics combined, including at least 5 credits of quantum mechanics and at least 5 credits chosen from among the areas of thermodynamics, statistical mechanics, statistical physics, and chemical dynamics.

All first-year students must register for CHPH 8601 during both fall and spring semesters and for CHEM 8066 during the spring semester of their first year in residence.

Required Courses
Any CHPH, CHEM, and PHYS courses at the 5xxx or 8xxx level may be used to satisfy degree requirements. Up to 8 credits in 4xxx-level courses may be used with approval from the director of graduate studies.

Students may count 1 credit each of the following towards the degree.

- CHEM 8066 - Professional Conduct of Chemical Research (1.0 cr)
- CHPH 8601 - Seminar: Modern Problems in Chemical Physics (1.0 cr)

Thesis Credits
Take 24 credits after passing preliminary oral exam.

- CHPH 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)
**Twin Cities Campus**  
**Chemistry M.S.**  
**Chemistry**  
**College of Science and Engineering**

Link to a list of faculty for this program.

**Contact Information:**  
Assistant to the Director of Graduate Studies, Department of Chemistry, University of Minnesota, 137 Smith Hall, 207 Pleasant St SE, Minneapolis, MN 55455 (612-626-7444 or 1-800-777-2431; fax: 612-626-7541)  
Email: chmapply@umn.edu  
Website: [http://www.chem.umn.edu](http://www.chem.umn.edu)

- Program Type: Master's  
- Requirements for this program are current for Fall 2018  
- Length of program in credits: 30  
- This program does not require summer semesters for timely completion.  
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

While modern research in chemistry is very interdisciplinary, graduate work in the Department of Chemistry falls broadly into the focus areas of analytical chemistry, chemical biology, environmental chemistry, inorganic chemistry, materials chemistry, organic chemistry, polymer chemistry, experimental physical chemistry, and computational chemistry.

**Program Delivery**  
This program is available:  
- via classroom (the majority of instruction is face-to-face)

**Prerequisites for Admission**  
An undergraduate degree in chemistry or a related field is required for admission. The preferred minimum undergraduate GPA for admittance to the program is 3.20.

Other requirements to be completed before admission:  
Applicants must offer the substantial equivalent of the courses in analytical, inorganic, organic, and physical chemistry that are required of undergraduate majors in the University of Minnesota chemistry curriculum. They must also have at least one year of college physics, plus college mathematics through calculus.

Three letters of recommendation and scores from the GRE general test are required for all applications. International applicants are expected to provide scores of at least 587 (paper), 240 (computer), or 95 (Internet) on the TOEFL, as well as GRE scores.

A Subject GRE score is not required but if available will help the admission committee to make better decisions, in particular in cases where undergraduate transcripts are more difficult to evaluate (which is especially true for international applicants, who are strongly encouraged to submit the GRE subject score). The Subject GRE can be taken in chemistry or a related discipline.

**Special Application Requirements:**  
Applications for fall semester must be completed by December 15 in order to be considered for fellowship support and teaching and research assistantships. Applications received after December 15 will be reviewed on a space available basis. The department prefers to admit for fall semester and will only consider spring admission under extenuating circumstances. More information is available at [chem.umn.edu/academics/graduate/prospective-students](http://chem.umn.edu/academics/graduate/prospective-students)

Applicants must submit their test score(s) from the following:  
- GRE

International applicants must submit score(s) from one of the following tests:  
- TOEFL  
  - Internet Based - Total Score: 95  
  - Internet Based - Speaking Score: 23  
- IELTS

© 2005 by the Regents of the University of Minnesota  
The University of Minnesota is an equal opportunity educator and employer.  
Information current as of August 31, 2018
Program Requirements

Plan A: Plan A requires 20 major credits, up to null credits outside the major, and 10 thesis credits. The final exam is oral.

Plan B: Plan B requires 30 major credits and up to null credits outside the major. The final exam is written. A capstone project is required.

Capstone Project: Each Plan B project should involve a combined total of approximately 160 hours (the equivalent of four full-time weeks) of library research, reading, and/or writing resulting in the preparation of a significant written document. Students who plan to work on Plan B projects independent of the Preliminary Examination should present a plan, after consultation with the chosen instructor for the Plan B project, outlining the number and content of their projects to the director of Graduate Studies. Projects should be completed to the satisfaction of the instructor; the final grade is determined by the instructor.

Plan C: Plan C requires 30 major credits and up to null credits outside the major. The is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 2.80 is required for students to remain in good standing.

MS students are expected to pass a proficiency exam during their first academic year in residence.

All first-year students must register for CHEM 8601 during both fall and spring semesters and for CHEM 8066 during the spring semester of their first year in residence.

All CHEM courses must be taken at the 5xxx or 8xxx level. Up to 8 credits in 4xxx-level courses from another department may be used with approval from the director of graduate studies.

Required Courses

Any 8xxx-level CHEM course can be used to satisfy degree requirements. Chem 5210 and 5755 will be accepted or consult with advisor for further 5xxx level course options.

Students may count one credit each of the following towards the degree.

CHEM 8066 - Professional Conduct of Chemical Research (1.0 cr)
CHEM 8601 - Seminar: Modern Problems in Chemistry (1.0 cr)

Plan A

Plan A requires 20 course credits and 10 thesis credits.

CHEM 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Plan B

Plan B requires 30 credits of coursework, including 8 credits in the two Plan B project courses.

CHEM 8081 - M.S. Plan B Project I (1.0 - 4.0 cr)
CHEM 8082 - M.S. Plan B Project II (1.0 - 4.0 cr)

Plan C

Plan C requires 30 course credits chosen in consultation with advisor.
Twin Cities Campus
Chemistry Minor
Chemistry
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Assistant to the Director of Graduate Studies, Department of Chemistry, University of Minnesota, 137 Smith Hall, 207 Pleasant St SE, Minneapolis, MN 55455 (612-626-7444 or 1-800-777-2431; fax: 612-626-7541)
Email: chmapply@umn.edu
Website: http://www.chem.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

While modern research in chemistry is very interdisciplinary, graduate work in the Department of Chemistry falls broadly into the focus areas of analytical chemistry, chemical biology, environmental chemistry, inorganic chemistry, materials chemistry, organic chemistry, polymer chemistry, experimental physical chemistry, and computational chemistry.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

Courses
Any 5xxx-level CHEM course taken on the A-F grading basis will satisfy the requirements for the minor. The following 5xxx-level courses will be accepted. Consult with the chemistry director of graduate studies for further options.
- CHEM 5210 - Materials Characterization (4.0 cr)
- CHEM 5755 - X-Ray Crystallography (4.0 cr)

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Masters
Six credits from CHEM courses at the 5xxx- or 8xxx-level are required.

Doctoral
Twelve credits from CHEM courses at the 5xxx- or 8xxx-level are required.
Twin Cities Campus
Chemistry Ph.D.
Chemistry
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Assistant to the Director of Graduate Studies, Department of Chemistry, University of Minnesota, 137 Smith Hall, 207 Pleasant St SE, Minneapolis, MN 55455 (612-626-7444 or 1-800-777-2431; fax: 612-626-7541)
Email: chmapply@umn.edu
Website: http://www.chem.umn.edu

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 48
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

While modern research in chemistry is very interdisciplinary, graduate work in the Department of Chemistry falls broadly into the focus areas of analytical chemistry, chemical biology, environmental chemistry, inorganic chemistry, materials chemistry, organic chemistry, polymer chemistry, experimental physical chemistry, and computational chemistry.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
An undergraduate degree in chemistry or a related field is required for admission. The preferred minimum undergraduate GPA for admittance to the program is 3.20.

Other requirements to be completed before admission:
Applicants must offer the substantial equivalent of the courses in analytical, inorganic, organic, and physical chemistry that are required of undergraduate majors in the University of Minnesota chemistry curriculum. They must also have at least one year of college physics, plus college mathematics through calculus.

Three letters of recommendation and scores from the GRE general test are required for all applications. International applicants are expected to provide scores of at least 587 (paper), 240 (computer), or 95 (Internet) on the TOEFL, as well as GRE scores.

A Subject GRE score is not required but if available will help the admission committee to make better decisions, in particular in cases where undergraduate transcripts are more difficult to evaluate (which is especially true for international applicants, who are strongly encouraged to submit the GRE subject score). The subject GRE can be taken in chemistry or a related discipline.

Special Application Requirements:
Applications for fall semester must be completed by December 15 in order to be considered for fellowship support and teaching and research assistantships. Applications received after December 15 will be reviewed on a space available basis. The department prefers to admit for fall semester and will only consider spring admission under extenuating circumstances. More information is available at chem.umn.edu/academics/graduate/prospective-students

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 95
  - Internet Based - Speaking Score: 23
- IELTS
Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
24 credits are required in the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

Students in the PhD program are expected to pass four of five proficiency examinations during their first year in residence. The exams, which are at the level of an advanced undergraduate course, are in analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, and physical chemistry. The exams are given during the chemistry first-year orientation program in August. In the event that a student does not pass the first exam, the exams are offered two more times during the academic year.

A minimum GPA of 3.00, 18 credits of coursework with a grade of B- or better, and passing grades on all four proficiency exams are required for students to remain in good standing.

All first-year students must register for CHEM 8601 during both fall and spring semesters and for CHEM 8066 during the spring semester of their first year in residence.

All CHEM courses must be taken at the 5xxx or 8xxx level. Up to 8 credits in 4xxx-level courses from another department may be used with approval from the director of graduate studies.

Required Courses
Any 8xxx-level CHEM course can be used to satisfy degree requirements. CHEM 5210 and 5755 will be accepted or consult with advisor for other 5xxx-level course options.

Students may count one credit each of the following towards the degree.

CHEM 8066 - Professional Conduct of Chemical Research (1.0 cr)
CHEM 8061 - Seminar: Modern Problems in Chemistry (1.0 cr)

Thesis Credits
Take 24 credits after passing preliminary oral exam.

CHEM 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)
Twin Cities Campus

Civil Engineering M.C.E.
CSENG Civil, Envrn & Geo-Eng (CEGE)

College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Civil, Environmental, and Geo-Engineering, University of Minnesota, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., Minneapolis, MN 55455 (612-625-5522; fax: 612-626-7750)
Email: cgeesps@umn.edu
Website: http://www.cege.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Civil Engineering

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Civil engineering emphases are available in environmental engineering (e.g., pollutant fate and transport, process modeling, soil and groundwater remediation, water and wastewater treatment), geomechanics (e.g., fracture and localization, groundwater flow, stability and liquefaction, wave and shock propagation), structural engineering (e.g., computational and structural mechanics, earthquake engineering, infrastructure performance and durability, new systems and materials), transportation engineering (e.g., intelligent transportation systems, pavement design and materials, transportation economics, traffic safety), and water resources engineering (e.g., earthscape processes, environmental and biological systems, hydrologic and climate dynamics, hydrodynamics, and turbulence).

The master of civil engineering (MCE) degree is designed for the practicing engineer who would like to obtain an advanced degree on a part-time or full-time basis. Students who intend to proceed to the Ph.D. program or who think they may later wish to be admitted to the Ph.D. program should apply for the master of science program. Students are expected to follow a coherent program of coursework in one of the following subareas of civil engineering: environmental, geomechanics, structural, transportation, or water resources engineering. The program is selected with the help of a faculty adviser and approved by the director of graduate studies. In addition to completing graduate-level courses, students must demonstrate professional competence either by carrying out and defending a design project or by taking a coursework-related final oral exam (without a project).

The degree typically takes 2-3 semesters (12-18 months) to complete on a full-time basis or 6-8 semesters on a part-time basis.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

An ABET-accredited, four-year bachelor's degree in engineering is required for admission.

Other requirements to be completed before admission:
The application deadlines are December 3 for fall admission and August 31 for spring admission. All materials must be submitted to the online application. Additional information is available at http://www.cege.umn.edu/prospective/graduate/how-to-apply.html

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
IELTS
- Total Score: 6.5

MELAB
- Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

Plan A: Plan A requires 20 major credits, up to null credits outside the major, and 10 thesis credits. The final exam is oral.

Plan C: Plan C requires 30 major credits and up to null credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

The MCE degree requires 30 credits and is offered under two plans. Plan A requires preparation of a thesis/design project. The thesis/design project must be carried out by the student in consultation with a faculty adviser. Plan C is a coursework-only degree program.

Required Courses

Any courses at the 5xxx and 8xxx level from the following programs may be used: AEM, AST, BBE, BMEN, CEGE, CHEM, CHEN, CSCI, EE, ESCI, IE, MATH, MATS, ME, PHYS, STAT. Use of 4xxx level courses must be approved by the Director of Graduate Studies and a maximum of 9 credits may be included. The following 4xxx courses may not be used: CEGE 4301, 4401, 4501, 4502, and 4522. Six credits in a minor may be included in the course credit total.

Seminar

Students may include one seminar credit in the course credit total.

CEGE 8200 - Seminar: Transportation (1.0 cr)
or CEGE 8300 - Seminar: Geomechanics (1.0 - 3.0 cr)
or CEGE 8400 - Seminar: Structures (1.0 cr)
or CEGE 8500 - Environmental Seminar (1.0 cr)

Plan A

Plan A requires a minimum of 20 course credits and 10 thesis credits for the design project.

CEGE 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Plan C

Plan C requires a minimum of 30 credits of coursework chosen in consultation with adviser and must include at least two courses at the 8xxx level. Students must also complete 100 hours of project work, give an oral presentation of no less than 10 minutes, and complete two hours of ethics training.
Civil engineering emphases are available in environmental engineering (e.g., pollutant fate and transport, process modeling, soil and groundwater remediation, water and wastewater treatment), geomechanics (e.g., fracture and localization, groundwater flow, stability and liquefaction, wave and shock propagation), structural engineering (e.g., computational and structural mechanics, earthquake engineering, infrastructure performance and durability, new systems and materials), transportation engineering (e.g., intelligent transportation systems, pavement design and materials, transportation economics, traffic safety), and water resources engineering (e.g., earthscape processes, environmental and biological systems, hydrologic and climate dynamics, hydrodynamics, and turbulence).

The master of science (M.S.) degree balances education in engineering fundamentals and design, and provides preparation for students wishing to pursue a career in industry, as well as those wanting to continue studies toward a Ph.D. degree. Programs range from the Plan C, which is a coursework-only program, to the Plan A, which balances coursework with research and development. The Plan C program is intended for practicing engineers who want to pursue a degree on a part-time basis, self-funded full-time students, as well as students who plan to continue on for a Ph.D. degree.

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A bachelor's degree in an engineering, basic science, or mathematics program is preferred.

Other requirements to be completed before admission:
Admission depends primarily on the applicant's academic record and letters of recommendation. Applicants who lack civil engineering training are often required to complete one or more appropriate courses from the undergraduate civil engineering program. Graduate credit is not awarded for such preparatory work.

Special Application Requirements:
The application deadlines are December 3 for fall admission and August 31 for spring admission. All materials must be submitted to the online application. Additional information is available at http://www.cege.umn.edu/prospective/graduate/how-to-apply.html

Applicants must submit their test score(s) from the following:
• GRE

International applicants must submit score(s) from one of the following tests:
• TOEFL
- Internet Based - Total Score: 79
- Internet Based - Writing Score: 21
- Internet Based - Reading Score: 19

**IELTS**
- Total Score: 6.5
**MELAB**
- Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

**Program Requirements**

**Plan A:** Plan A requires 20 major credits, up to null credits outside the major, and 10 thesis credits. The final exam is oral.

**Plan B:** Plan B requires 30 major credits and up to null credits outside the major. The final exam is oral.

**Plan C:** Plan C requires 30 major credits and up to null credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

The MS requires at least 30 credits and is offered under three plans. Plan A emphasizes research and preparation of a thesis; Plan B emphasizes coursework and a project; Plan C is coursework only. The Plan A thesis is written on a research project carried out in consultation with a faculty adviser. Under Plan B, students complete one to three Plan B papers as determined by the faculty adviser. Plan B papers can include computer programs, annotated bibliographies, field investigations, and analysis/design of special engineering problems. A program typically takes 18 to 24 months to complete.

**Required Courses**

Any courses at the 5xxx and 8xxx level from the following programs may be used: AEM, AST, BBE, BMEN, CEGE, CHEM, CHEN, CSCI, EE, ESCI, IE, MATH, MATS, ME, PHYS, STAT. Use of 4xxx level courses must be approved by the Director of Graduate Studies and a maximum of 9 credits may be included. The following 4xxx courses may not be used: CEGE 4301, 4401, 4501, 4502, and 4522. Six credits in a minor may be included in the course credit total.

**Seminar**

Students may count one seminar credit towards the course credit requirement.

- CEGE 8200 - Seminar: Transportation (1.0 cr)
- CEGE 8300 - Seminar: Geomechanics (1.0 - 3.0 cr)
- CEGE 8400 - Seminar: Structures (1.0 cr)
- CEGE 8500 - Environmental Seminar (1.0 cr)

**Plan A**

Plan A requires a minimum of 20 course credits and 10 thesis credits.

- CEGE 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

**Plan B**

Plan B requires a minimum of 30 credits, which includes at least 27 course credits and a maximum of 3 credits of CEGE 8094 for the Plan B project.

- CEGE 8094 - Civil Engineering Research (1.0 - 4.0 cr)

**Plan C**

Plan C requires 30 course credits and must include at least 2 courses at the 8xxx-level. Students must also complete 100 hours of project work, give an oral presentation of no less than 10 minutes, and complete two hours of ethics training.

**Joint- or Dual-degree Coursework:** Dual Master's Degree in Civil Engineering and Industrial and Systems Engineering (Transportation Engineering Focus): Student may take a total of 15 credits in common among the academic programs. Dual Master's Degree in Civil Engineering and Urban and Regional Planning (Transportation or Environmental Engineering Focus): Student may take a total of 18 credits in common among the academic programs.
Program Sub-plans
A sub-plan is not required for this program. Students may not complete the program with more than one sub-plan.

Integrated B.C.E./M.S. - Civil Engineering
The department offers an integrated Bachelor of Civil Engineering (BCE) and Master of Science (MS) in Civil Engineering. The integrated BCE/MS program offers students the opportunity to earn a bachelor's degree and a master's degree in five years. These programs offer several benefits: streamlined admissions from the undergraduate to the graduate program (GRE not required); flexibility in fulfilling required courses for both degrees during the senior year (up to 16 credits can be transferred to the graduate program); and eligibility for teaching and research assistantships.

Both the BCE and MS degrees must be completed in their entirety, with no courses shared between them. The graduate degree cannot be earned before the undergraduate requirements are satisfied. Admitted students who decide not to complete the MS degree are permitted to count credits originally planned for the graduate program toward their BCE technical electives.

Eligibility Requirements:
Application to the Combined Program is open to civil engineering undergraduates who:
- are within 32 credits of completing the requirements for the bachelors degree;
- have a faculty advisor selected prior to admission; and
- hold a cumulative GPA of 3.3 or higher.

Integrated B.GeoE./M.S. - Civil Engineering
The department offers an integrated Bachelor of Geoengineering (B.GeoE.) and Master of Science (MS) in Civil Engineering. Benefits, eligibility requirements, and degree-completion requirements outlined for the BCE/MS integrated program also apply to the B.GeoE./MS

Integrated B.Env.E./M.S. - Civil Engineering
The department offers an integrated Bachelor of Environmental Engineering (B.Env.E.) and Master of Science (MS) in Civil Engineering. Benefits, eligibility requirements, and degree-completion requirements outlined for the BCE/MS integrated program also apply to the B.Env.E./MS
Twin Cities Campus
Civil Engineering Minor
CSENG Civil, Envirn & Geo-Eng (CEGE)
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Civil, Environmental, and Geo-Engineering, University of Minnesota, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., Minneapolis, MN 55455 (612-625-5522; fax: 612-626-7750)
Email: cegesps@umn.edu
Website: http://www.cege.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Civil engineering emphases are available in environmental engineering (e.g., pollutant fate and transport, process modeling, soil and groundwater remediation, water and wastewater treatment), geomechanics (e.g., fracture and localization, groundwater flow, stability and liquefaction, wave and shock propagation), structural engineering (e.g., computational and structural mechanics, earthquake engineering, infrastructure performance and durability, new systems and materials), transportation engineering (e.g., intelligent transportation systems, pavement design and materials, transportation economics, traffic safety), and water resources engineering (e.g., earthscape processes, environmental and biological systems, hydrologic and climate dynamics, hydrodynamics, and turbulence).

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

Minor courses should be chosen from one of the following subareas.

Environmental/Water Resources Engineering
CEGE 55xx
CEGE 85xx

Geomechanics
CEGE 53xx
CEGE 83xx

Structural Engineering
CEGE 54xx
CEGE 84xx

Transportation Engineering
CEGE 52xx
CEGE 82XX
Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Master's
For a master's minor, two or more 5xxx or 8xxx level courses from the same subarea of civil engineering are required, for a total of 6 or more credits.

Doctoral
For the doctoral minor, four or more 5xxx or 8xxx level courses from one or two subareas of civil engineering are required for a total of 12 or more credits.
Twin Cities Campus

Civil Engineering Ph.D.
CSENG Civil, Envirn & Geo-Eng (CEGE)

College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Civil, Environmental, and Geo-Engineering, University of Minnesota, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., Minneapolis, MN 55455 (612-625-5522; fax: 612-626-7750)
Email: cegesps@umn.edu
Website: http://www.cege.umn.edu

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 60
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Civil engineering emphases are available in environmental engineering (e.g., pollutant fate and transport, process modeling, soil and groundwater remediation, water and wastewater treatment), geomechanics (e.g., fracture and localization, groundwater flow, stability and liquefaction, wave and shock propagation), structural engineering (e.g., computational and structural mechanics, earthquake engineering, infrastructure performance and durability, new systems and materials), transportation engineering (e.g., intelligent transportation systems, pavement design and materials, transportation economics, traffic safety), and water resources engineering (e.g., earthscape processes, environmental and biological systems, hydrologic and climate dynamics, hydrodynamics, and turbulence).

The PhD degree couples independent research with coursework in a comprehensive program for those wishing to attain mastery of their field. The PhD degree demands the ability and desire to pursue independent and original studies and can be earned with emphasis in environmental, geomechanics, structural, transportation, or water resources engineering. Research performance, as judged by preparation of a dissertation on an independently pursued research topic, is the primary requirement for the PhD degree.

Students enter the PhD program two to four years following the bachelor's degree, normally after completing the MS degree. The PhD program is typically completed in four to six years following the bachelor's degree. Each program of study is designed in consultation with a faculty adviser to meet the special needs of the student, although programs must be approved by the director of graduate studies.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A bachelor's degree in an engineering, basic science, or mathematics program is preferred.

Other requirements to be completed before admission:
Admission depends primarily on the applicant's academic record and letters of recommendation. Applicants who lack civil engineering training are often required to complete one or more appropriate courses from the undergraduate civil engineering program. Graduate credit is not awarded for such preparatory work.

Special Application Requirements:
The application deadlines are December 3 for fall admission and August 31 for spring admission. All materials must be submitted to the online application. Additional information is available at http://www.cege.umn.edu/prospective/graduate/how-to-apply.html

Applicants must submit their test score(s) from the following:
• GRE
International applicants must submit score(s) from one of the following tests:

- **TOEFL**
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
- **IELTS**
  - Total Score: 6.5
- **MELAB**
  - Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

**Program Requirements**

36 credits are required in the major.

24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

A typical program consists of 36 credits of coursework beyond the bachelor's degree, plus 24 thesis credits. Credits earned in a MS program may be presented in partial fulfillment of the PhD requirements. Rigid requirements for the number of 8xxx courses appropriate for PhD programs have not been set; nonetheless, the PhD represents the highest level of scholarly achievement and coursework should be selected accordingly.

**Required Courses**

Any courses at the 5xxx and 8xxx level from the following programs may be used: AEM, AST, BBE, BMEN, CEGE, CHEM, CHEN, CSCI, EE, ESCI, IE, MATH, MATS, ME, PHYS, STAT. Use of 4xxx level courses must be approved by the Director of Graduate Studies and a maximum of 9 credits may be included. The following 4xxx courses may not be used: CEGE 4301, 4401, 4501, 4502, and 4522. The 36 course credits may include 12 credits in a minor.

**Seminar**

Students may count up to two seminar credits for the Ph.D. program in the 36-credit total.

- CEGE 8200 - Seminar: Transportation (1.0 cr)
- or CEGE 8300 - Seminar: Geomechanics (1.0 - 3.0 cr)
- or CEGE 8400 - Seminar: Structures (1.0 cr)
- or CEGE 8500 - Environmental Seminar (1.0 cr)

**Thesis Credits**

Take 24 credits after passing preliminary oral exam

- CEGE 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)
Twin Cities Campus
Computer Science M.C.S.
Computer Science and Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Computer Science and Engineering, University of Minnesota, 4-192 Keller Hall, 200 Union Street SE, Minneapolis, MN 55455 (612- 625-4002; fax: 612-625-0572)
Email: csgradmn@umn.edu
Website: http://www.cs.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 31
- This program does not require summer semesters for timely completion.
- Degree: Master of Computer Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The graduate program in computer science offers coursework from across a broad spectrum of theoretical and applied computer science, combined with research opportunities in nearly all areas of the field. Faculty members advise students in such areas as algorithms and theoretical computer science; numerical, parallel, and high-performance computing; distributed computing and systems; artificial intelligence, robotics, and computer vision; databases and data mining; human-computer interaction and information systems; graphics and visualization; software engineering and programming languages; computer architecture and compilers; networking; bioinformatics and computational biology; and computer security. In addition, students may choose a course of study that integrates research in computer science with applications in other fields.

Computer science degrees include the M.C.S., a professional coursework-only degree designed for the professional student that is intended to be a terminal degree.

The department also offers the MS (Plan A with thesis, Plan B with project, or coursework-only Plan C with coursework-based projects) and the PhD. In addition, the department supports a master of science in software engineering (M.S.S.E.) degree.

Faculty from the Department of Computer Science and Engineering also participate in a variety of other graduate programs, including BioInformatics and Computational Biology, Health Informatics, Cognitive Science, Scientific Computation, and Human Factors and Ergonomics.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)
- completely online (all program coursework can be completed online)
- primarily online (at least 80% of the instruction for the program is online with short, intensive periods of face-to-face coursework)
- partially online (between 50% to 80% of instruction is online)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

Applicants must have a undergraduate or graduate degree in a major with a substantial background in computer science and engineering.

Other requirements to be completed before admission:
The names and email addresses of three recommenders are required; they will be asked to upload their letters of recommendation to the university system. The department only accepts students for fall admission; the application deadline is March 1. Additional information is available at https://www.cs.umn.edu/admissions/graduate/mcs

Special Application Requirements:
Applicants with an inadequate background must resolve any deficiencies before applying to the program.
International applicants must submit score(s) from one of the following tests:

- **TOEFL**
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550

- **IELTS**
  - Total Score: 6.5
  - Reading Score: 6.5
  - Writing Score: 6.5

- **MELAB**
  - Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

---

**Program Requirements**

**Plan C:** Plan C requires 31 major credits and 0 credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 3.00 is required for students to remain in good standing.

The M.C.S. is a coursework-only degree requiring 31 course credits. At least 16 credits must be in computer science courses, including one course from each of the 3 breadth areas: theory, systems, and applications (9 credits); and 1 credit of colloquium (CSCI 8970). At least 6 credits must be in computer science 8xxx-level courses, in addition to the colloquium. The remaining 15 course credits may be taken in the major field or any supporting field as defined in the graduate handbook.

All major courses must be taken on the A-F grading option and students must maintain a GPA above 3.00 after completing 8 credits.

**Breadth Courses**

Take one course from each subject area.

**Applications**

Take 1 or more course(s) from the following:

- CSCI 5115 - User Interface Design, Implementation and Evaluation (3.0 cr)
- CSCI 5125 - Collaborative and Social Computing (3.0 cr)
- CSCI 5271 - Introduction to Computer Security (3.0 cr)
- CSCI 5461 - Functional Genomics, Systems Biology, and Bioinformatics (3.0 cr)
- CSCI 5471 - Modern Cryptography (3.0 cr)
- CSCI 5511 - Artificial Intelligence I (3.0 cr)
- CSCI 5512 - Artificial Intelligence II (3.0 cr)
- CSCI 5521 - Introduction to Machine Learning (3.0 cr)
- CSCI 5523 - Introduction to Data Mining (3.0 cr)
- CSCI 5551 - Introduction to Intelligent Robotic Systems (3.0 cr)
- CSCI 5561 - Computer Vision (3.0 cr)
- CSCI 5607 - Fundamentals of Computer Graphics I (3.0 cr)
- CSCI 5608 - Fundamentals of Computer Graphics II (3.0 cr)
- CSCI 5609 - Visualization (3.0 cr)
- CSCI 5611 - Animation & Planning in Games (3.0 cr)
- CSCI 5619 - Virtual Reality and 3D Interaction (3.0 cr)
- CSCI 5707 - Principles of Database Systems (3.0 cr)

**Architecture, Systems and Software**

Take 1 or more course(s) from the following:

- CSCI 5103 - Operating Systems (3.0 cr)
- CSCI 5106 - Programming Languages (3.0 cr)
- CSCI 5161 - Introduction to Compilers (3.0 cr)
- CSCI 5204 - Advanced Computer Architecture (3.0 cr)
- CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
• CSCI 5221 - Foundations of Advanced Networking (3.0 cr)
• CSCI 5231 - Wireless and Sensor Networks (3.0 cr)
• CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
• CSCI 5708 - Architecture and Implementation of Database Management Systems (3.0 cr)
• CSCI 5801 - Software Engineering I (3.0 cr)
• CSCI 5802 - Software Engineering II (3.0 cr)

**Theory and Algorithms**
Take 1 or more course(s) from the following:
• CSCI 5302 - Analysis of Numerical Algorithms (3.0 cr)
• CSCI 5304 - Computational Aspects of Matrix Theory (3.0 cr)
• CSCI 5403 - Computational Complexity (3.0 cr)
• CSCI 5421 - Advanced Algorithms and Data Structures (3.0 cr)
• CSCI 5481 - Computational Techniques for Genomics (3.0 cr)
• CSCI 5525 - Machine Learning (3.0 cr)

**Colloquium Credits**
Take 1 credit of CS colloquium
CSCI 8970 - Computer Science Colloquium (1.0 cr)

**Computer Science Courses**
Students may choose additional coursework from this list or consult with their adviser for further options.
Take 0 or more credit(s) from the following:
• CSCI 5103 - Operating Systems (3.0 cr)
• CSCI 5105 - Introduction to Distributed Systems (3.0 cr)
• CSCI 5106 - Programming Languages (3.0 cr)
• CSCI 5115 - User Interface Design, Implementation and Evaluation (3.0 cr)
• CSCI 5125 - Collaborative and Social Computing (3.0 cr)
• CSCI 5143 - Real-Time and Embedded Systems (3.0 cr)
• CSCI 5161 - Introduction to Compilers (3.0 cr)
• CSCI 5204 - Advanced Computer Architecture (3.0 cr)
• CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
• CSCI 5231 - Wireless and Sensor Networks (3.0 cr)
• CSCI 5271 - Introduction to Computer Security (3.0 cr)
• CSCI 5302 - Analysis of Numerical Algorithms (3.0 cr)
• CSCI 5304 - Computational Aspects of Matrix Theory (3.0 cr)
• CSCI 5403 - Computational Complexity (3.0 cr)
• CSCI 5421 - Advanced Algorithms and Data Structures (3.0 cr)
• CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
• CSCI 5461 - Functional Genomics, Systems Biology, and Bioinformatics (3.0 cr)
• CSCI 5481 - Computational Techniques for Genomics (3.0 cr)
• CSCI 5511 - Artificial Intelligence I (3.0 cr)
• CSCI 5512 - Artificial Intelligence II (3.0 cr)
• CSCI 5521 - Introduction to Machine Learning (3.0 cr)
• CSCI 5523 - Introduction to Data Mining (3.0 cr)
• CSCI 5525 - Machine Learning (3.0 cr)
• CSCI 5551 - Introduction to Intelligent Robotic Systems (3.0 cr)
• CSCI 5552 - Sensing and Estimation in Robotics (3.0 cr)
• CSCI 5561 - Computer Vision (3.0 cr)
• CSCI 5607 - Fundamentals of Computer Graphics I (3.0 cr)
• CSCI 5608 - Fundamentals of Computer Graphics II (3.0 cr)
• CSCI 5611 - Animation & Planning in Games (3.0 cr)
• CSCI 5619 - Virtual Reality and 3D Interaction (3.0 cr)
• CSCI 5707 - Principles of Database Systems (3.0 cr)
• CSCI 5708 - Architecture and Implementation of Database Management Systems (3.0 cr)
• CSCI 5715 - From GPS and Virtual Globes to Spatial Computing (3.0 cr)
• CSCI 5801 - Software Engineering I (3.0 cr)
• CSCI 5802 - Software Engineering II (3.0 cr)
• CSCI 5980 - Special Topics in Computer Science (1.0 - 3.0 cr)
• CSCI 8115 - Human-Computer Interaction and User Interface Technology (3.0 cr)
• CSCI 8205 - Parallel Computer Organization (3.0 cr)
• CSCI 8211 - Advanced Computer Networks and Their Applications (3.0 cr)
• CSCI 8271 - Security and Privacy in Computing (3.0 cr)
• CSCI 8363 - Numerical Linear Algebra in Data Exploration (3.0 cr)
• CSCI 8551 - Intelligent Agents (3.0 cr)
• CSCI 8715 - Spatial Data Science Research (3.0 cr)
• CSCI 8735 - Advanced Database Systems (3.0 cr)
Twin Cities Campus
Computer Science M.S.
Computer Science and Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Computer Science and Engineering, University of Minnesota, 4-192 Keller Hall, 200 Union Street SE, Minneapolis, MN 55455 (612-625-4002; fax: 612-625-0572)
Email: csgradmn@umn.edu
Website: http://www.cs.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 31
- This program does not require summer semesters for timely completion.
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The graduate program in computer science offers coursework from across a broad spectrum of theoretical and applied computer science, combined with research opportunities in nearly all areas of the field. The graduate program's faculty members advise students in such areas as algorithms and theoretical computer science; numerical, parallel, and high-performance computing; distributed computing and systems; artificial intelligence, robotics, and computer vision; databases and data mining; human-computer interaction and information systems; graphics and visualization; software engineering and programming languages; computer architecture and compilers; networking; bio-informatics and computational biology; and computer security. In addition, students may choose a course of study that integrates research in computer science with applications in other fields.

Computer science degrees include the MS (offered Plan A with thesis, Plan B with project, or coursework-only Plan C with coursework-based projects), the MCS (a terminal, coursework-only degree), and the PhD. The department also supports a master of science in software engineering (MSSE) degree.

Faculty from the Department of Computer Science and Engineering also participate in a variety of other graduate programs, including bioinformatics and computational biology, health informatics, cognitive science, scientific computation, and human factors and ergonomics.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)
- completely online (all program coursework can be completed online)
- primarily online (at least 80% of the instruction for the program is online with short, intensive periods of face-to-face coursework)
- partially online (between 50% to 80% of instruction is online)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.25.

A degree in any major with a substantial background in computer science is required; a computer science major is preferred.

Other requirements to be completed before admission:
Applicants with an inadequate background must resolve any deficiencies before applying to the program.

The program requires all applicants to complete the University's online application. The names and email addresses of three recommenders are required; Scores from the General (Aptitude) Test of the GRE are required for MS program applicants. Master's students are accepted for fall admission only. The application deadline is March 1. Additional information is available at https://www.cs.umn.edu/admissions/graduate

Applicants must submit their test score(s) from the following:
- GRE
International applicants must submit score(s) from one of the following tests:

- **TOEFL**
  - Internet Based - Total Score: 85
  - Internet Based - Writing Score: 23
  - Internet Based - Reading Score: 23
  - Paper Based - Total Score: 550

- **IELTS**
  - Total Score: 6.5
  - Reading Score: 6.5
  - Writing Score: 6.5

- **MELAB**
  - Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

**Program Requirements**

**Plan A:** Plan A requires 21 major credits, 0 credits outside the major, and 10 thesis credits. The final exam is written and oral.

**Plan B:** Plan B requires 31 major credits and 0 credits outside the major. The final exam is oral.

**Plan C:** Plan C requires 31 major credits and 0 credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 3.25 is required for students to remain in good standing.

The MS requires a minimum of 31 credits and is offered under three plans. All plans require students to take one course from each of the 3 breadth areas in computer science (9 credits): theory and algorithms; architecture, systems and software; and applications; and 1 credit of colloquium (CSCI 8970).

A minimum of 6 credits in computer science 8xxx-level courses, in addition to the colloquium, must be included in the required coursework for Plan A and Plan C; Plan B students must include a minimum of 3 credits in computer science 8xxx-level courses, in addition to the colloquium and Plan B project credits.

Plan A requires 13 credits in computer science coursework, including the breadth courses and colloquium credit, plus 10 thesis credits. The remaining 8 credits may be taken in the major field or any related field as defined by the graduate handbook.

Plan B and Plan C require 16 credits in computer science coursework, including the breadth courses and colloquium credit. Plan B students must also include 3 credits of the project course, CSCI 8760. The remaining 15 credits may be taken in the major field or in any related field.

**Breadth Courses**

Students in all plans must take 3 breadth requirement courses, one from each subject area.

**Applications**

Take 1 or more course(s) from the following:

- **CSCI 5115** - User Interface Design, Implementation and Evaluation (3.0 cr)
- **CSCI 5125** - Collaborative and Social Computing (3.0 cr)
- **CSCI 5271** - Introduction to Computer Security (3.0 cr)
- **CSCI 5461** - Functional Genomics, Systems Biology, and Bioinformatics (3.0 cr)
- **CSCI 5471** - Modern Cryptography (3.0 cr)
- **CSCI 5511** - Artificial Intelligence I (3.0 cr)
- **CSCI 5512** - Artificial Intelligence II (3.0 cr)
- **CSCI 5521** - Introduction to Machine Learning (3.0 cr)
- **CSCI 5523** - Introduction to Data Mining (3.0 cr)
- **CSCI 5551** - Introduction to Intelligent Robotic Systems (3.0 cr)
• CSCI 5561 - Computer Vision (3.0 cr)
• CSCI 5607 - Fundamentals of Computer Graphics I (3.0 cr)
• CSCI 5608 - Fundamentals of Computer Graphics II (3.0 cr)
• CSCI 5609 - Visualization (3.0 cr)
• CSCI 5611 - Animation & Planning in Games (3.0 cr)
• CSCI 5619 - Virtual Reality and 3D Interaction (3.0 cr)
• CSCI 5707 - Principles of Database Systems (3.0 cr)

**Architecture, Systems and Software**
Take 1 or more course(s) from the following:
• CSCI 5103 - Operating Systems (3.0 cr)
• CSCI 5106 - Programming Languages (3.0 cr)
• CSCI 5161 - Introduction to Compilers (3.0 cr)
• CSCI 5204 - Advanced Computer Architecture (3.0 cr)
• CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
• CSCI 5221 - Foundations of Advanced Networking (3.0 cr)
• CSCI 5231 - Wireless and Sensor Networks (3.0 cr)
• CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
• CSCI 5708 - Architecture and Implementation of Database Management Systems (3.0 cr)
• CSCI 5801 - Software Engineering I (3.0 cr)
• CSCI 5802 - Software Engineering II (3.0 cr)

**Theory and Algorithms**
Take 1 or more course(s) from the following:
• CSCI 5302 - Analysis of Numerical Algorithms (3.0 cr)
• CSCI 5304 - Computational Aspects of Matrix Theory (3.0 cr)
• CSCI 5403 - Computational Complexity (3.0 cr)
• CSCI 5421 - Advanced Algorithms and Data Structures (3.0 cr)
• CSCI 5481 - Computational Techniques for Genomics (3.0 cr)
• CSCI 5525 - Machine Learning (3.0 cr)

**Colloquium Credits**
Students must take 1 credit of CS Colloquium
CSCI 8970 - Computer Science Colloquium (1.0 cr)

**Computer Science Courses**
Students may choose additional coursework from this list or consult with their advisor for further options.
Take 0 or more credit(s) from the following:
• CSCI 5103 - Operating Systems (3.0 cr)
• CSCI 5105 - Introduction to Distributed Systems (3.0 cr)
• CSCI 5106 - Programming Languages (3.0 cr)
• CSCI 5115 - User Interface Design, Implementation and Evaluation (3.0 cr)
• CSCI 5125 - Collaborative and Social Computing (3.0 cr)
• CSCI 5143 - Real-Time and Embedded Systems (3.0 cr)
• CSCI 5161 - Introduction to Compilers (3.0 cr)
• CSCI 5204 - Advanced Computer Architecture (3.0 cr)
• CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
• CSCI 5231 - Wireless and Sensor Networks (3.0 cr)
• CSCI 5271 - Introduction to Computer Security (3.0 cr)
• CSCI 5302 - Analysis of Numerical Algorithms (3.0 cr)
• CSCI 5304 - Computational Aspects of Matrix Theory (3.0 cr)
• CSCI 5403 - Computational Complexity (3.0 cr)
• CSCI 5421 - Advanced Algorithms and Data Structures (3.0 cr)
• CSCI 5461 - Functional Genomics, Systems Biology, and Bioinformatics (3.0 cr)
• CSCI 5481 - Computational Techniques for Genomics (3.0 cr)
• CSCI 5511 - Artificial Intelligence I (3.0 cr)
• CSCI 5512 - Artificial Intelligence II (3.0 cr)
• CSCI 5521 - Introduction to Machine Learning (3.0 cr)
• CSCI 5523 - Introduction to Data Mining (3.0 cr)
• CSCI 5525 - Machine Learning (3.0 cr)
• CSCI 5551 - Introduction to Intelligent Robotic Systems (3.0 cr)
• CSCI 5552 - Sensing and Estimation in Robotics (3.0 cr)
• CSCI 5561 - Computer Vision (3.0 cr)
• CSCI 5607 - Fundamentals of Computer Graphics I (3.0 cr)
• CSCI 5608 - Fundamentals of Computer Graphics II (3.0 cr)
• CSCI 5611 - Animation & Planning in Games (3.0 cr)
• CSCI 5619 - Virtual Reality and 3D Interaction (3.0 cr)
• CSCI 5707 - Principles of Database Systems (3.0 cr)
• CSCI 5708 - Architecture and Implementation of Database Management Systems (3.0 cr)
• CSCI 5715 - From GPS and Virtual Globes to Spatial Computing (3.0 cr)
• CSCI 5801 - Software Engineering I (3.0 cr)
• CSCI 5802 - Software Engineering II (3.0 cr)
• CSCI 5980 - Special Topics in Computer Science (1.0 - 3.0 cr)
• CSCI 8115 - Human-Computer Interaction and User Interface Technology (3.0 cr)
• CSCI 8205 - Parallel Computer Organization (3.0 cr)
• CSCI 8211 - Advanced Computer Networks and Their Applications (3.0 cr)
• CSCI 8271 - Security and Privacy in Computing (3.0 cr)
• CSCI 8363 - Numerical Linear Algebra in Data Exploration (3.0 cr)
• CSCI 8551 - Intelligent Agents (3.0 cr)
• CSCI 8715 - Spatial Data Science Research (3.0 cr)
• CSCI 8735 - Advanced Database Systems (3.0 cr)
• CSCI 8970 - Computer Science Colloquium (1.0 cr)

Plan A
Plan A students must take 10 thesis credits.
CSCI 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Plan B
Plan B requires 3 credits of the Plan B project course, CSCI 8760. The Plan B project is a significant project demonstrating the student's familiarity with the tools of research, the capability to work independently, and the ability to effectively relate their results to their committee. A written report describing the Plan B project must be approved by the advisor. A copy of the report should be provided to the committee members at least 1 week before the oral presentation.
CSCI 8760 - Plan B Project (3.0 cr)

Plan C
Plan C is a coursework only degree. Students must complete a minimum of 100 hours of course-based project work, a written research report, and an oral presentation within CSCI courses taken for graduate credit. Students can count at most 3 credits of the following directed research/independent study courses toward their degree plan: CSCI 5994, 8994, 5991, and 8991.
Twin Cities Campus
Computer Science Minor
Computer Science and Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Computer Science and Engineering, University of Minnesota, 4-192 Keller Hall, 200 Union Street S.E., Minneapolis, MN 55455 (612-625-4002; fax: 612-625-0572)
Email: admissions@cs.umn.edu
Website: http://www.cs.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 9
- Length of program in credits (Doctorate): 13
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The graduate program in computer science offers coursework from across a broad spectrum of theoretical and applied computer science, combined with research opportunities in nearly all areas of the field. Faculty members advise students in such areas as algorithms and theoretical computer science; numerical, parallel, and high-performance computing; distributed computing and systems; artificial intelligence, robotics, and computer vision; databases and data mining; human-computer interaction and information systems; graphics and visualization; software engineering and programming languages; computer architecture and compilers; networking; bioinformatics and computational biology; and computer security. In addition, students may choose a course of study that integrates research in computer science with applications in other fields.

Computer science degrees include the M.C.S., the M.S. (Plan A with thesis, Plan B with project, or coursework-only Plan C with coursework-based projects), and the Ph.D. The department also supports a master of science in software engineering (M.S.S.E.) degree.

Faculty from the Department of Computer Science and Engineering also participate in a variety of other graduate programs, including BioInformatics and Computational Biology, Health Informatics, Cognitive Science, Scientific Computation and Human Factors and Ergonomics.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Master's
A minor in computer science for master's students majoring in other fields must include 9 credits of graduate courses in CSCI. The
colloquium credit may not be included. There is a limit of one 4xxx course and a requirement of at least one 8xxx course or a 5xxx course that has a prerequisite of a 5xxx course. These courses must be taken on the A/F grading scale and a minimum GPA of 3.00 is expected.

Doctoral
A minor in computer science for Ph.D. students majoring in other fields must include 13 credits of graduate courses in CSCI, and should include the colloquium credit. There is a limit of one 4xxx course and a requirement of at least one 8xxx course or a 5xxx course that has a prerequisite of a 5xxx course. These courses must be taken on the A/F grading scale and a minimum GPA of 3.25 is expected.

Colloquium Credit
CSCI 8970 - Computer Science Colloquium (1.0 cr)
Twin Cities Campus

Computer Science Ph.D.
Computer Science and Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Computer Science and Engineering, University of Minnesota, 4-192 Keller Hall, 200 Union Street S.E., Minneapolis, MN 55455 (612- 625-4002; fax: 612-625-0572)
Email: csadmit@umn.edu
Website: http://www.cs.umn.edu

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 55
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The graduate program in computer science offers coursework from across a broad spectrum of theoretical and applied computer science, combined with research opportunities in nearly all areas of the field. Faculty members advise students in such areas as algorithms and theoretical computer science; numerical, parallel, and high-performance computing; distributed computing and systems; artificial intelligence, robotics, and computer vision; databases and data mining; human-computer interaction and information systems; graphics and visualization; software engineering and programming languages; computer architecture and compilers; networking; bioinformatics and computational biology; machine learning; and computer security. In addition, students may choose a course of study that integrates research in computer science with applications in other fields.

Computer science degrees include the PhD, as well as the M.C.S. (a terminal, coursework-only degree), and the MS (offered Plan A with thesis, Plan B with project, or coursework-only Plan C with coursework-based projects). The department also supports a master of science in software engineering (M.S.S.E.) degree.

Faculty from the Department of Computer Science and Engineering also participate in a variety of other graduate programs, including BioInformatics and Computational Biology, Health Informatics, Cognitive Science, Scientific Computation and Human Factors and Ergonomics.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.45.

A degree in any major with a substantial background in computer science is required; a computer science major is preferred.

Other requirements to be completed before admission:
The program requires all applicants to complete the department's online application, as well as the University's online application. The names and email addresses of three recommenders are required; they will be asked to upload their letters of recommendation to the CS&E online application only. Scores from the General (Aptitude) Test of the GRE are required for PhD program applicants. PhD students are accepted for fall admission only. The application deadline is April 1. Students seeking financial aid must apply by December 5. Additional information is available at https://www.cs.umn.edu/admissions/graduate

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 85
  - Internet Based - Writing Score: 23
Program Requirements
16 to 25 credits are required in the major.
6 to 15 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 3.45 is required for students to remain in good standing.

The PhD requires a total of 55 credits consisting of 31 course credits and 24 thesis credits. Of the 31 course credits, 16 must be in computer science courses and at least 6 from outside the major. The 16 major credits must include five 3-credit courses that fulfill the breadth requirement in three different areas: theory and algorithms; architecture, systems and software; and applications; plus 1 credit of colloquium (CSCI 8970).

The remaining 9 credits may be taken as additional graduate-level courses in the major or in any supporting field. Students are recommended to take CSCI 8001/2 Introduction to Research in Computer Science I and II and a directed research course (CSCI 8994).

Students are expected to complete all courses in their degree program with a GPA of at least 3.45. All courses must be taken for graduate credit and on the A-F grading basis.

All doctoral students must demonstrate background knowledge in computer science as explained in the program requirements at: https://www.cs.umn.edu/academics/graduate/phd/bg-req

Breadth Requirement Courses
Students must take a total of 5 courses (typically 15 credits): one from each of the three subject areas and the remaining two from any of the three subject areas.

Take 5 or more course(s) from the following:

Theory and Algorithms
Take 1 or more course(s) from the following:
- CSCI 5302 - Analysis of Numerical Algorithms (3.0 cr)
- CSCI 5304 - Computational Aspects of Matrix Theory (3.0 cr)
- CSCI 5403 - Computational Complexity (3.0 cr)
- CSCI 5421 - Advanced Algorithms and Data Structures (3.0 cr)
- CSCI 5481 - Computational Techniques for Genomics (3.0 cr)
- CSCI 5525 - Machine Learning (3.0 cr)

Architecture, Systems and Software
Take 1 or more course(s) from the following:
- CSCI 5103 - Operating Systems (3.0 cr)
- CSCI 5105 - Introduction to Distributed Systems (3.0 cr)
- CSCI 5106 - Programming Languages (3.0 cr)
- CSCI 5161 - Introduction to Compilers (3.0 cr)
- CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
- CSCI 5221 - Foundations of Advanced Networking (3.0 cr)
- CSCI 5231 - Wireless and Sensor Networks (3.0 cr)
- CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
- CSCI 5708 - Architecture and Implementation of Database Management Systems (3.0 cr)
- CSCI 5801 - Software Engineering I (3.0 cr)
• CSCI 5802 - Software Engineering II (3.0 cr)
• CSCI 5204 - Advanced Computer Architecture (3.0 cr)

Applications
Take 1 or more course(s) from the following:
• CSCI 5115 - User Interface Design, Implementation and Evaluation (3.0 cr)
• CSCI 5125 - Collaborative and Social Computing (3.0 cr)
• CSCI 5271 - Introduction to Computer Security (3.0 cr)
• CSCI 5471 - Modern Cryptography (3.0 cr)
• CSCI 5511 - Artificial Intelligence I (3.0 cr)
• CSCI 5512 - Artificial Intelligence II (3.0 cr)
• CSCI 5521 - Introduction to Machine Learning (3.0 cr)
• CSCI 5523 - Introduction to Data Mining (3.0 cr)
• CSCI 5551 - Introduction to Intelligent Robotic Systems (3.0 cr)
• CSCI 5561 - Computer Vision (3.0 cr)
• CSCI 5607 - Fundamentals of Computer Graphics I (3.0 cr)
• CSCI 5608 - Fundamentals of Computer Graphics II (3.0 cr)
• CSCI 5609 - Visualization (3.0 cr)
• CSCI 5611 - Animation & Planning in Games (3.0 cr)
• CSCI 5619 - Virtual Reality and 3D Interaction (3.0 cr)
• CSCI 5707 - Principles of Database Systems (3.0 cr)

Supporting Program
Take 6 credits in courses outside of computer science. These credits may be used toward the requirements for a doctoral minor.

Colloquium Credits
Take 1 credit of CS colloquium.
CSCI 8970 - Computer Science Colloquium (1.0 cr)

Thesis Credits
Take 24 credits after passing preliminary oral exam.
CSCI 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)

Computer Science Courses
The remaining 9 credits of coursework may be taken in the major field or any supporting field. Students may choose courses from this list or consult with their advisor for additional options.
Take 0 or more credit(s) from the following:
• CSCI 5103 - Operating Systems (3.0 cr)
• CSCI 5105 - Introduction to Distributed Systems (3.0 cr)
• CSCI 5106 - Programming Languages (3.0 cr)
• CSCI 5115 - User Interface Design, Implementation and Evaluation (3.0 cr)
• CSCI 5117 - Developing the Interactive Web (3.0 cr)
• CSCI 5125 - Collaborative and Social Computing (3.0 cr)
• CSCI 5161 - Introduction to Compilers (3.0 cr)
• CSCI 5204 - Advanced Computer Architecture (3.0 cr)
• CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
• CSCI 5221 - Foundations of Advanced Networking (3.0 cr)
• CSCI 5231 - Wireless and Sensor Networks (3.0 cr)
• CSCI 5271 - Introduction to Computer Security (3.0 cr)
• CSCI 5302 - Analysis of Numerical Algorithms (3.0 cr)
• CSCI 5304 - Computational Aspects of Matrix Theory (3.0 cr)
• CSCI 5403 - Computational Complexity (3.0 cr)
• CSCI 5421 - Advanced Algorithms and Data Structures (3.0 cr)
• CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
• CSCI 5461 - Functional Genomics, Systems Biology, and Bioinformatics (3.0 cr)
• CSCI 5471 - Modern Cryptography (3.0 cr)
• CSCI 5481 - Computational Techniques for Genomics (3.0 cr)
• CSCI 5511 - Artificial Intelligence I (3.0 cr)
• CSCI 5512 - Artificial Intelligence II (3.0 cr)
• CSCI 5521 - Introduction to Machine Learning (3.0 cr)
• CSCI 5523 - Introduction to Data Mining (3.0 cr)
• CSCI 5525 - Machine Learning (3.0 cr)
• CSCI 5551 - Introduction to Intelligent Robotic Systems (3.0 cr)
• CSCI 5561 - Computer Vision (3.0 cr)
• CSCI 5607 - Fundamentals of Computer Graphics I (3.0 cr)
• CSCI 5611 - Animation & Planning in Games (3.0 cr)
• CSCI 5619 - Virtual Reality and 3D Interaction (3.0 cr)
• CSCI 5707 - Principles of Database Systems (3.0 cr)
• CSCI 5708 - Architecture and Implementation of Database Management Systems (3.0 cr)
• CSCI 5715 - From GPS and Virtual Globes to Spatial Computing (3.0 cr)
• CSCI 5801 - Software Engineering I (3.0 cr)
• CSCI 5802 - Software Engineering II (3.0 cr)
• CSCI 5980 - Special Topics in Computer Science (1.0 - 3.0 cr)
• CSCI 5991 - Independent Study (1.0 - 3.0 cr)
• CSCI 5994 - Directed Research (1.0 - 3.0 cr)
• CSCI 8001 - Introduction to Research in Computer Science I (1.0 cr)
• CSCI 8002 - Introduction to Research in Computer Science, II (2.0 cr)
• CSCI 8115 - Human-Computer Interaction and User Interface Technology (3.0 cr)
• CSCI 8205 - Parallel Computer Organization (3.0 cr)
• CSCI 8363 - Numerical Linear Algebra in Data Exploration (3.0 cr)
• CSCI 8442 - Computational Geometry and Applications (3.0 cr)
• CSCI 8551 - Intelligent Agents (3.0 cr)
• CSCI 8735 - Advanced Database Systems (3.0 cr)
• CSCI 8801 - Advanced Software Engineering (3.0 cr)
• CSCI 8980 - Special Advanced Topics in Computer Science (1.0 - 3.0 cr)
• CSCI 8991 - Independent Study (1.0 - 3.0 cr)
• CSCI 8994 - Directed Research in Computer Science (1.0 - 3.0 cr)
Twin Cities Campus

Cyber Security Minor

Technological Leadership Institute

College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Technological Leadership Institute, University of Minnesota, 290 McNamara Alumni Center, 200 Oak Street SE, Minneapolis MN 55455
(612-624-5474; fax: 612-624-7510)
Email: damian@umn.edu
Website: http://tli.umn.edu

- Program Type: Graduate free-standing minor
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 8
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The minor in the Cyber Security program is administered by the Technological Leadership Institute (TLI) in the College of Science and Engineering. The program integrates the fields of technology, security, and management, to provide students with the skills and insights to assume a leadership role in cyber security, or continue their field of study with a focus on cyber security and its role in organizations.

The curriculum applies fundamental concepts of business management, organizational leadership, and risk management techniques and strategies, each as applied in the context of cyber security, to empower engineering, technology, and business professionals to adapt and lead in the emerging field of cyber security. Each class will include exercises that inform students on those cyber security topics, and give them an opportunity to practice the fundamental skills of communications, teamwork, and project management.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

Required Courses
These core courses are designed to be taken in sequence.
ST 8661 - Securing Cyberspace (Fundamentals) (3.0 cr)
ST 8662 - Securing Cyberspace - Advanced (3.0 cr)

Program Sub-plans
Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

Masters

Elective Courses
Take 2 or more credit(s) from the following:
- ST 8113 - Information and Cyber Security (2.0 cr)
• ST 8113 - Information and Cyber Security (2.0 cr)
• ST 8513 - Cyber Threat Intelligence (2.0 cr)
• CSCI 5271 - Introduction to Computer Security (3.0 cr)
• CSCI 5471 - Modern Cryptography (3.0 cr)
• CSCI 8271 - Security and Privacy in Computing (3.0 cr)

Doctoral Elective Courses
Take 6 or more credit(s) from the following:
• ST 8113 - Information and Cyber Security (2.0 cr)
• ST 8513 - Cyber Threat Intelligence (2.0 cr)
• CSCI 5271 - Introduction to Computer Security (3.0 cr)
• CSCI 5471 - Modern Cryptography (3.0 cr)
• CSCI 8271 - Security and Privacy in Computing (3.0 cr)
Twin Cities Campus
Data Science Certificate
Computer Science and Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Data Science Graduate Program, Department of Computer Science and Engineering, University of Minnesota, 4-192 Keller Hall, 200 Union Street S.E., Minneapolis, MN 55455 (612-625-4002; fax: 612-625-0572).
Email: datascience@umn.edu
Website: http://datascience.umn.edu

- Program Type: Post-baccalaureate credit certificate/licensure/endorsement
- Requirements for this program are current for Fall 2018
- Length of program in credits: 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The Data Science Certificate program provides a strong foundation in the science of Big Data and its analysis by gathering in a single program the knowledge, expertise, and educational assets in data collection and management, data analytics, scalable data-driven pattern discovery, and the fundamental concepts behind these methods.

Students who graduate from this 2-semester certificate program will learn the state-of-the-art methods for treating Big Data and be exposed to the cutting edge methods and theory forming the basis for the next generation of Big Data technology.

Program Delivery
This program is available:
- partially online (between 50% to 80% of instruction is online)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A bachelor's degree from an accredited college or university in computer science, math, statistics, engineering, natural sciences, or a related field.

Other requirements to be completed before admission:
The undergraduate degree must include statistics, calculus, multivariable calculus, linear algebra, and mathematical software environments such as Matlab or R or the equivalent, programming languages such as C+, C++, Java, programming experience including algorithms and data structures normally taught in beginning computer science courses either as part of the undergraduate degree or subsequent work experience.

Special Application Requirements:
Admission application deadlines: rolling. Applicants are considered for Fall or Spring admission and decisions are made after all applications are received following the close of the application cycle. Application instructions can be found here: https://datascience.umn.edu/admissions

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Writing Score: 23
  - Internet Based - Reading Score: 23
  - Paper Based - Total Score: 550
- IELTS
  - Total Score: 6.5
- MELAB
  - Part 1 (Composition) score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).
Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 3.0 is required for students to remain in good standing.

The Data Science certificate requires a minimum of 12 credits consisting of one course from each of the three emphasis areas, plus one course chosen from any of the three emphasis areas.

Statistics
Take 1 or more course(s) totaling 3 or more credit(s) from the following:
- STAT 5101 - Theory of Statistics I (4.0 cr)
  or STAT 5102 - Theory of Statistics II (4.0 cr)
  or STAT 5302 - Applied Regression Analysis (4.0 cr)
  or STAT 5401 - Applied Multivariate Methods (3.0 cr)
  or STAT 5511 - Time Series Analysis (3.0 cr)
  or STAT 8051 - Advanced Regression Techniques: linear, nonlinear and nonparametric methods (3.0 cr)
  or PUBH 7440 - Introduction to Bayesian Analysis (3.0 cr)

Algorithmics
Take 1 or more course(s) totaling 3 or more credit(s) from the following:
- CSCI 5521 - Introduction to Machine Learning (3.0 cr)
  or CSCI 5523 - Introduction to Data Mining (3.0 cr)
  or CSCI 5525 - Machine Learning (3.0 cr)
  or EE 8591 - Predictive Learning from Data (3.0 cr)
  or PUBH 8475 - Statistical Learning and Data Mining (3.0 cr)

Infrastructure and Large Scale Computing
Take 1 or more course(s) totaling 3 or more credit(s) from the following:
- CSCI 5105 - Introduction to Distributed Systems (3.0 cr)
  or CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
  or CSCI 5707 - Principles of Database Systems (3.0 cr)
  or CSCI 8980 - Special Advanced Topics in Computer Science (1.0 - 3.0 cr)
  or EE 5351 - Applied Parallel Programming (3.0 cr)
  or EE 8367 - Parallel Computer Organization (3.0 cr)
**Twin Cities Campus**

**Data Science M.S.**

*Computer Science and Engineering*

**College of Science and Engineering**

Link to a list of faculty for this program.

**Contact Information:**
Data Science Graduate Program, Department of Computer Science and Engineering, University of Minnesota, 4-192 Keller Hall, 200 Union Street S.E., Minneapolis, MN 55455 (612-625-4002; fax: 612-625-0572).
Email: datascience@umn.edu
Website: [http://datascience.umn.edu](http://datascience.umn.edu)

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 31
- This program does not require summer semesters for timely completion.
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the [General Information](#) section of the catalog website for requirements that apply to all major fields.

The MS in data science program provides a strong foundation in the science of Big Data and its analysis by gathering in a single program the knowledge, expertise, and educational assets in data collection and management, data analytics, scalable data-driven pattern discovery, and the fundamental concepts behind these methods.

Students who graduate from this regular 2 year master's program will learn the state-of-the-art methods for treating Big Data, be exposed to the cutting edge methods and theory forming the basis for the next generation of Big Data technology, and will complete a project demonstrating that they can use the fundamental concepts to design innovative methods for new application areas arising from business, government, security, medicine, biology, physical sciences, and the environment.

**Program Delivery**

This program is available:
- via classroom (the majority of instruction is face-to-face)

**Prerequisites for Admission**

The preferred undergraduate GPA for admittance to the program is 3.00.

A bachelor's degree from an accredited college or university in computer science, math, statistics, engineering, natural sciences, or a related field.

Other requirements to be completed before admission:

The undergraduate degree must include statistics, calculus, multivariable calculus, linear algebra, and mathematical software environments such as Matlab or R or the equivalent, programming languages such as C++, C#, Java, programming experience including algorithms and data structures normally taught in beginning computer science courses either as part of the undergraduate degree or subsequent work experience.

**Special Application Requirements:**

Admission application deadlines: February 1st international applicants, March 1st domestic applicants. Applicants are only considered for fall admission and decisions are made after all applications are received following the close of the application cycle. Application instructions can be found here: [https://datascience.umn.edu/admissions](https://datascience.umn.edu/admissions)

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Writing Score: 23
  - Internet Based - Reading Score: 23
  - Paper Based - Total Score: 550
- IELTS
Total Score: 6.5
MELAB
Part 1 (Composition) score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

Plan B: Plan B requires 31 major credits and up to null credits outside the major. The final exam is written and oral. A capstone project is required.

Capstone Project: Students must complete 3 credit hours of capstone project coursework supervised by a faculty member.

The final examination for the Capstone Project may be oral, written, or both. The format of the final exam is decided between the student, the adviser, and the director of graduate studies, and is based on what is most appropriate for the student's project. The final oral examination, if it is used, is a closed examination open only to the final oral examination committee and the student.

This program may be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

The program requires a total of 31 credits consisting of 6 credits each from the three emphasis areas: statistics, algorithms, and infrastructure and large scale computing; 9 credits in approved electives, 3 credits of which must be at the 8xxx level; 1 credit of research colloquium; and 3 credits for the capstone project.

Statistics

Short List
Take one course from the short list and one additional statistics course from any in this emphasis for a total of 6 or more credits.
Take 2 or more course(s) totaling 6 or more credit(s) from the following:
- STAT 5101 - Theory of Statistics I (4.0 cr)
- STAT 5102 - Theory of Statistics II (4.0 cr)
- STAT 5302 - Applied Regression Analysis (4.0 cr)
- STAT 5401 - Applied Multivariate Methods (3.0 cr)
- STAT 5511 - Time Series Analysis (3.0 cr)
- STAT 8051 - Advanced Regression Techniques: linear, nonlinear and nonparametric methods (3.0 cr)
- PUBH 7440 - Introduction to Bayesian Analysis (3.0 cr)

Additional Courses
Take 0 or more course(s) totaling 0 or more credit(s) from the following:
- PUBH 8401 - Linear Models (4.0 cr)
- PUBH 8432 - Probability Models for Biostatistics (3.0 cr)
- PUBH 7405 - Biostatistics: Regression (4.0 cr)
- PUBH 7430 - Statistical Methods for Correlated Data (3.0 cr)
- PUBH 8442 - Bayesian Decision Theory and Data Analysis (3.0 cr)
- EE 5531 - Probability and Stochastic Processes (3.0 cr)
- EE 8581 - Detection and Estimation Theory (3.0 cr)

Algorithmics

Short List
Take one course from the short list and one additional course from any in this emphasis for a total of 6 or more credits.
Take 2 or more course(s) totaling 6 or more credit(s) from the following:
- CSCI 5521 - Introduction to Machine Learning (3.0 cr)
- CSCI 5523 - Introduction to Data Mining (3.0 cr)
- CSCI 5525 - Machine Learning (3.0 cr)
- EE 8591 - Predictive Learning from Data (3.0 cr)
- PUBH 8475 - Statistical Learning and Data Mining (3.0 cr)

Additional Courses
Take 0 or more course(s) totaling 0 or more credit(s) from the following:
- CSCI 5302 - Analysis of Numerical Algorithms (3.0 cr)
- CSCI 5304 - Computational Aspects of Matrix Theory (3.0 cr)
- CSCI 5511 - Artificial Intelligence I (3.0 cr)
- CSCI 5512 - Artificial Intelligence II (3.0 cr)
• CSCI 5609 - Visualization (3.0 cr)
• CSCI 8314 - Sparse Matrix Computations (3.0 cr)
• EE 5239 - Introduction to Nonlinear Optimization (3.0 cr)
• EE 5251 - Optimal Filtering and Estimation (3.0 cr)
• EE 5542 - Adaptive Digital Signal Processing (3.0 cr)
• EE 5551 - Multiscale and Multirate Signal Processing (3.0 cr)
• EE 5561 - Image Processing and Applications (3.0 cr)
• EE 5581 - Information Theory and Coding (3.0 cr)
• EE 5585 - Data Compression (3.0 cr)
• EE 8231 - Optimization Theory (3.0 cr)
• IE 5531 - Engineering Optimization I (4.0 cr)
• IE 8534 - Advanced Topics in Operations Research (4.0 cr)

Infrastructure and Large Scale Computing

Short List
Take one course from the short list and one additional course from any in this emphasis for a total of 6 or more credits.
Take 2 or more course(s) totaling 6 or more credit(s) from the following:
• CSCI 5105 - Introduction to Distributed Systems (3.0 cr)
• CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
• CSCI 5707 - Principles of Database Systems (3.0 cr)
• CSCI 8980 - Special Advanced Topics in Computer Science (1.0 - 3.0 cr)
• EE 5351 - Applied Parallel Programming (3.0 cr)
• EE 8367 - Parallel Computer Organization (3.0 cr)
• CSCI 5708 - Architecture and Implementation of Database Management Systems (3.0 cr)

Additional Courses
Take 0 or more course(s) totaling 0 or more credit(s) from the following:
• CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
• CSCI 5231 - Wireless and Sensor Networks (3.0 cr)
• CSCI 5271 - Introduction to Computer Security (3.0 cr)
• CSCI 5715 - From GPS and Virtual Globes to Spatial Computing (3.0 cr)
• CSCI 8701 - Overview of Database Research (3.0 cr)
• CSCI 8715 - Spatial Data Science Research (3.0 cr)
• EE 5371 - Computer Systems Performance Measurement and Evaluation (3.0 cr)
• EE 5381 - Telecommunications Networks (3.0 cr)
• EE 5501 - Digital Communication (3.0 cr)

Electives
Take 3 elective courses for 9 graduate-credits. 3 credits must be at the 8xxx level. DSCI 8760 does not satisfy the elective requirement. Students may choose courses from this list or consult with their adviser for further options. Examples include 5xxx & 8xxx special topics classes in CSCI, EE, STAT, & PUBH (Biostat).
Take 3 or more course(s) totaling 9 or more credit(s) from the following:
• CSCI 5461 - Functional Genomics, Systems Biology, and Bioinformatics (3.0 cr)
• CSCI 5561 - Computer Vision (3.0 cr)
• CSCI 8271 - Security and Privacy in Computing (3.0 cr)
• CSCI 8363 - Numerical Linear Algebra in Data Exploration (3.0 cr)
• CSCI 8715 - Spatial Data Science Research (3.0 cr)
• CSCI 8725 - Databases for Bioinformatics (3.0 cr)
• PUBH 8445 - Statistics for Human Genetics and Molecular Biology (3.0 cr)
• PUBH 8446 - Advanced Statistical Genetics and Genomics (3.0 cr)
• PUBH 8472 - Spatial Biostatistics (3.0 cr)
• MATH 5467 - Introduction to the Mathematics of Image and Data Analysis (4.0 cr)

Research Colloquium
DSCI 8970 - Data Science M.S. Colloquium (1.0 cr)

Capstone Course
DSCI 8760 - Data Science M.S. Plan B Project (3.0 cr)
Twin Cities Campus

Data Science Minor

Computer Science and Engineering

College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:

Data Science Graduate Program, Department of Computer Science and Engineering, University of Minnesota, 4-192 Keller Hall, 200 Union Street S.E., Minneapolis, MN 55455 (612-625-4002; fax: 612-625-0572).

Email: datascience@umn.edu

Website: http://datascience.umn.edu

• Program Type: Graduate minor related to major
• Requirements for this program are current for Fall 2018
• Length of program in credits (Masters): 9
• Length of program in credits (Doctorate): 12
• This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The Data Science Minor provides a strong foundation in the science of Big Data and its analysis by gathering together the knowledge, expertise, and educational assets in data collection and management, data analytics, scalable data-driven pattern discovery, and the fundamental concepts behind these methods. Students completing this program will learn the state-of-the-art methods for treating Big Data and be exposed to the cutting edge methods and theory forming the basis for the next generation of Big Data technology.

Program Delivery

This program is available:

• partially online (between 50% to 80% of instruction is online)

Prerequisites for Admission

Currently enrolled in a University of Minnesota M.S. or Ph.D. program.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

Use of 4xxx courses towards program requirements is not permitted.

Courses must be taken at the University of Minnesota Twin Cities Campus and on the A/F grading scale. Transfer coursework will not be accepted. A 3.0 GPA must be maintained in the courses used for the Data Science minor.

All students must take one course from each of the three emphasis areas for a total of at least 9 credits. Doctoral students must take an additional electives course for at least 3 credits.

Algorithmics

Take 1 or more course(s) totaling 3 or more credit(s) from the following:

• CSCI 5521 - Introduction to Machine Learning (3.0 cr)
• CSCI 5523 - Introduction to Data Mining (3.0 cr)
• CSCI 5525 - Machine Learning (3.0 cr)
• EE 8591 - Predictive Learning from Data (3.0 cr)
• PUBH 7475 - Statistical Learning and Data Mining (3.0 cr)

Statistics

Take 1 or more course(s) totaling 3 or more credit(s) from the following:
• STAT 5101 - Theory of Statistics I (4.0 cr)
• STAT 5102 - Theory of Statistics II (4.0 cr)
• STAT 5302 - Applied Regression Analysis (4.0 cr)
• STAT 5511 - Time Series Analysis (3.0 cr)
• STAT 5401 - Applied Multivariate Methods (3.0 cr)
• STAT 8051 - Advanced Regression Techniques: linear, nonlinear and nonparametric methods (3.0 cr)
• PUBH 7440 - Introduction to Bayesian Analysis (3.0 cr)

Infrastructure and Large Scale Computing
Take 1 or more course(s) totaling 3 or more credit(s) from the following:
• CSCI 5105 - Introduction to Distributed Systems (3.0 cr)
• CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
• CSCI 5707 - Principles of Database Systems (3.0 cr)
• CSCI 8980 - Special Advanced Topics in Computer Science (1.0 - 3.0 cr)
• EE 5351 - Applied Parallel Programming (3.0 cr)

• Parallel Computer Organization
  Either CSCI 8205 or EE 8367. These courses are cross-listed.
  • CSCI 8205 - Parallel Computer Organization (3.0 cr)
  or EE 8367 - Parallel Computer Organization (3.0 cr)

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Master's
The master's minor requires one course from each of the three emphasis areas for a total of 9 credits.

Doctoral
In addition to one course from each of the three emphasis areas, doctoral students take one elective course from the following to complete the 12-credit minimum.

Biochemistry Electives (6 Credits)
Students cannot use a course from the department housing their degree program as an elective.
Take 1 or more course(s) totaling 3 or more credit(s) from the following:
• STAT 5101 - Theory of Statistics I (4.0 cr)
• STAT 5102 - Theory of Statistics II (4.0 cr)
• STAT 5302 - Applied Regression Analysis (4.0 cr)
• STAT 5511 - Time Series Analysis (3.0 cr)
• STAT 5401 - Applied Multivariate Methods (3.0 cr)
• STAT 8051 - Advanced Regression Techniques: linear, nonlinear and nonparametric methods (3.0 cr)
• PUBH 7440 - Introduction to Bayesian Analysis (3.0 cr)
• PUBH 8401 - Linear Models (4.0 cr)
• PUBH 8432 - Probability Models for Biostatistics (3.0 cr)
• PUBH 7405 - Biostatistics: Regression (4.0 cr)
• PUBH 7430 - Statistical Methods for Correlated Data (3.0 cr)
• PUBH 7460 - Advanced Statistical Computing (3.0 cr)
• PUBH 8442 - Bayesian Decision Theory and Data Analysis (3.0 cr)
• EE 5531 - Probability and Stochastic Processes (3.0 cr)
• EE 8581 - Detection and Estimation Theory (3.0 cr)
• CSCI 5521 - Introduction to Machine Learning (3.0 cr)
• CSCI 5523 - Introduction to Data Mining (3.0 cr)
• CSCI 5525 - Machine Learning (3.0 cr)
• EE 8591 - Predictive Learning from Data (3.0 cr)
• PUBH 7475 - Statistical Learning and Data Mining (3.0 cr)
• CSCI 5302 - Analysis of Numerical Algorithms (3.0 cr)
• CSCI 5304 - Computational Aspects of Matrix Theory (3.0 cr)
• CSCI 5511 - Artificial Intelligence I (3.0 cr)
• CSCI 5512 - Artificial Intelligence II (3.0 cr)
• CSCI 5609 - Visualization (3.0 cr)
• CSCI 8314 - Sparse Matrix Computations (3.0 cr)
• EE 5239 - Introduction to Nonlinear Optimization (3.0 cr)
• EE 5251 - Optimal Filtering and Estimation (3.0 cr)
• EE 5542 - Adaptive Digital Signal Processing (3.0 cr)
• EE 5551 - Multiscale and Multirate Signal Processing (3.0 cr)
• EE 5561 - Image Processing and Applications (3.0 cr)
• EE 5581 - Information Theory and Coding (3.0 cr)
• EE 5585 - Data Compression (3.0 cr)
• EE 8231 - Optimization Theory (3.0 cr)
• IE 5531 - Engineering Optimization I (4.0 cr)
• IE 8534 - Advanced Topics in Operations Research (4.0 cr)
• CSCI 5105 - Introduction to Distributed Systems (3.0 cr)
• CSCI 5451 - Introduction to Parallel Computing: Architectures, Algorithms, and Programming (3.0 cr)
• CSCI 5707 - Principles of Database Systems (3.0 cr)
• CSCI 8980 - Special Advanced Topics in Computer Science (1.0 - 3.0 cr)
• EE 5351 - Applied Parallel Programming (3.0 cr)
• CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
• CSCI 5231 - Wireless and Sensor Networks (3.0 cr)
• CSCI 5271 - Introduction to Computer Security (3.0 cr)
• CSCI 5708 - Architecture and Implementation of Database Management Systems (3.0 cr)
• CSCI 5715 - From GPS and Virtual Globes to Spatial Computing (3.0 cr)
• CSCI 5980 - Special Topics in Computer Science (1.0 - 3.0 cr)
• CSCI 8701 - Overview of Database Research (3.0 cr)
• CSCI 8715 - Spatial Data Science Research (3.0 cr)
• CSCI 8725 - Databases for Bioinformatics (3.0 cr)
• EE 5371 - Computer Systems Performance Measurement and Evaluation (3.0 cr)
• EE 5381 - Telecommunications Networks (3.0 cr)
• EE 5501 - Digital Communication (3.0 cr)
• EE 8367 - Parallel Computer Organization (3.0 cr)
• CSCI 8205 - Parallel Computer Organization (3.0 cr)
Twin Cities Campus
Earth Sciences M.S.
Department of Earth Sciences
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Earth Sciences, University of Minnesota, John T. Tate Hall-Suite 150, 116 Church St. SE, Minneapolis, MN 55455 (612-624-1333; fax: 612-625-3819)
Email: esci@umn.edu
Website: http://www.esci.umn.edu/programs/graduate

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The modern earth sciences are a remarkable synthesis of the physical and biological sciences. They are at the forefront of inquiry into and solutions of most of the major issues involving the global environment: climate, oceans, freshwater in all its forms, natural resources, and natural disasters. Like no other field, they integrate all the systems, from surface to great depth, from physics to chemistry to biology, and over all of geologic time and all geographic scales. The program includes the fields of structural geology, tectonics, petrology, hydrogeology, geomorphology, sedimentology, surface processes, geochemistry, biogeochemistry, biogeology, chemical oceanography, mineralogy, mineral and rock magnetism, rock and mineral physics, geodynamics, seismology, geostatistics, planetary geology, and geophysics and applied geophysics.

Students may accommodate other areas of interest such as engineering geology, environmental geology, materials science, soil science, and paleoecology by choosing a minor or supporting field from outside the program.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A bachelor's degree in geology, geophysics, earth and material sciences, chemistry, physics, biology, or environmental science.

Other requirements to be completed before admission:
At least one year each of study in calculus, chemistry, and physics is required. In general, an outstanding academic record is expected.

Special Application Requirements:
Materials required for a complete application file include the student's statement of purpose, three letters of recommendation, transcripts, official GRE scores, and the Application for Admission. Applications are considered at any time; however, to be considered for financial aid, all materials must be submitted by December 15. Studies may begin in any semester or summer session, although fall semester is preferable. IMPORTANT: Refer to the Graduate Programs section of the department website (http://www.esci.umn.edu/programs/gradprospective) for a listing of all required application materials and preferred method of submission.

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
- Internet Based - Total Score: 79
- Internet Based - Writing Score: 21
- Internet Based - Reading Score: 19
- Paper Based - Total Score: 550

• IELTS
  - Total Score: 6.5
• MELAB
  - Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

Plan A: Plan A requires 14 major credits, 6 credits outside the major, and 10 thesis credits. The final exam is oral.

Plan B: Plan B requires 14 to 22 major credits and 8 to 16 credits outside the major. The final exam is written and oral. A capstone project is required.

Capstone Project: Students must demonstrate familiarity with the tools of research or scholarship in their track, the ability to work independently, and the ability to present the results of their investigation effectively, by completing one or more projects, which may take the form of a research paper, presentation of research results, or completion of a faculty-supervised research experience. The Plan B project(s) should involve a minimum combined total of approximately 120 hours (the equivalent of three full-time weeks) of work.

Plan C: Plan C requires 14 to 21 major credits and 9 to 16 credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 2.80 is required for students to remain in good standing.

At the onset of studies, a coursework "compact" will be developed with the student, his/her advisor, and the graduate studies committee. The compact will be reviewed annually to assure timely progress and revise as needed.

The masters degree is offered under Plan A (thesis), Plan B (project), or Plan C (coursework). Plan A and Plan B students must choose one of five tracks in the earth sciences program: geology, geophysics, biogeology, hydrogeology, or earth sciences. Plan C students may only choose the hydrogeology track. Tracks carry coursework requirements that are part of the student's course compact.

A maximum of 9 credits of 4xxx-level coursework may be used towards programs requirements.

Required Courses

All students must complete ESCI 8001, preferably in the first year.

ESCI 8001 - Introductory Graduate Seminar (2.0 cr)

Plan A
Plan A requires 14 credits in the major (including the track requirements); 6 credits in a minor or in related fields outside ESCI, and 10 thesis credits.

ESCI 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Plan B
Plan B requires 14 credits in the major (including the track requirements) and 8 credits outside ESCI, which can include a minor. The remaining 8 credits can be taken in the major or in any supporting field. Up to 3 credits of ESCI 8994 may be used for the project requirement.

ESCI 8994 - Research in Earth Sciences (1.0 - 4.0 cr)

Plan C
Plan C requires 14 credits in the major (including the track requirements) and 9 credits outside ESCI, which can include a minor. The remaining 7 credits can be taken in the major or in any supporting field. Plan C students may only choose the Hydrogeology track.

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
Program Sub-plans
Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

Biogeology
This sub-plan is limited to students completing the program under Plan A or Plan B.

Biogeology represents a rapidly growing area at the intersection between Earth and the life sciences. It includes research in microbial evolution and biochemistry, microbe/mineral chemical interactions, the role of organisms in basic geological processes, the principles through which organisms or organic compounds can be used to reconstruct surface conditions, biogeochemical cycling, pollution control and remediation, the origin of life on Earth, and astrobiology. This is a broad field that is moving in new and exciting directions, and witnessing explosive growth in understanding the variety of ways biology mediates geology and vice versa. Many of the most basic earth surface processes are now seen as intimately biological with rates and pathways dictated by organic processes. Understanding the importance of these processes, quantifying them through time and place, and learning to utilize and/or control them will be major components of earth sciences research in the 21st century.

Required Courses
Take 6 or more credit(s) from the following:
- ESCI 8402 - Biogeochemical Cycles in the Ocean (3.0 cr)
- ESCI 8801 - Geomicrobiology (3.0 cr)

Earth Sciences
This sub-plan is limited to students completing the program under Plan A or Plan B.

This generalist track exists for students whose curriculum and/or thesis (paper or project for MS Plan B) do not fit any of the other four tracks. Because it is not specific to a discipline, there are no mandatory courses in the major apart from the introductory graduate seminar, a minimum of 6 additional graduate-level credits in the major program, 12 supporting program credits or completion of all requirements for a minor, and thesis credits. A curriculum specific to the student will be set through the compact process.

6-credit minimum; courses determined on an individual basis.

Geology
This sub-plan is limited to students completing the program under Plan A or Plan B.

Geology uses field observation, laboratory work, analog and computer modeling, chemical and biological probes and assays to understand Earth's coupled rock, water and biological systems, the underlying processes, and their history of interaction as evidenced in the rock record.

Required Courses
Take 6 or more credit(s) from the following:
- ESCI 5302 - Isotope Geology (3.0 cr)
- ESCI 5351 - Geochemical Modeling of Aqueous Systems (3.0 cr)
- ESCI 5353 - Electron Microprobe Theory and Practice (3.0 cr)
- ESCI 5502 - Advanced Structural Geology (3.0 cr)
- ESCI 5503 - Advanced Petrology (3.0 cr)
- ESCI 5601W - Advanced Sedimentology [WI] (4.0 cr)
- ESCI 5705 - Limnogeology and Paleoenvironment (3.0 cr)

Geophysics
This sub-plan is limited to students completing the program under Plan A or Plan B.

Geophysics uses remote sensing probes (seismic waves, potential fields, etc.), laboratory simulation of deep earth conditions and computer modeling of fluid and continuum mechanical dynamics to investigate the structure, composition, history and dynamics of solid Earth and other planets.

Required Courses
- ESCI 4211 - Solid Earth Geophysics I (3.0 cr)
Take 1 or more course(s) totaling 3 or more credit(s) from the following:
- ESCI 4212 - Solid Earth Geophysics II (3.0 cr)
Hydrogeology

Hydrogeology uses direct observation and remote sensing, computer modeling and laboratory simulation to constrain the interaction of water and rock in Earth's shallow subsurface. Freshwater is Earth's most precious and increasingly overexploited resource. Hydrogeology is a key discipline in the effective shepherding of this important reserve. This track establishes a baseline curriculum for hydrogeology at the graduate level. The compact process will identify additional coursework appropriate to the student's prior training and research directions.

Required Courses

ESCI 4702 - General Hydrogeology (4.0 cr)

Take 1 or more course(s) totaling 3 or more credit(s) from the following:

• ESCI 5205 - Fluid Mechanics in Earth and Environmental Sciences (3.0 cr)
• ESCI 5971 - Field Hydrogeology (2.0 cr)
Twin Cities Campus
Earth Sciences Minor
Department of Earth Sciences
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Earth Sciences, University of Minnesota, John T. Tate Hall-Suite 150, 116 Church St. SE, Minneapolis, MN 55455 (612-624-1333; fax: 612-625-3819)
Email: esci@umn.edu
Website: http://www.esci.umn.edu/programs/graduate

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The modern earth sciences are a remarkable synthesis of the physical and biological sciences. They are at the forefront of inquiry into and solutions of most of the major issues involving the global environment: climate, oceans, freshwater in all its forms, natural resources, and natural disasters. Like no other field, they integrate all the systems, from surface to great depth, from physics to chemistry to biology, and over all of geologic time and all geographic scales. The program includes the fields of structural geology, tectonics, petrology, hydrogeology, geomorphology, sedimentology, surface processes, geochemistry, biogeochemistry, biogeology, chemical oceanography, mineralogy, mineral and rock magnetism, rock and mineral physics, geodynamics, seismology, geostatistics, planetary geology, and geophysics and applied geophysics.

Students may accommodate other areas of interest such as engineering geology, environmental geology, materials science, soil science, and paleoecology by choosing a minor or supporting field from outside the program.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

The minor is established individually with approval by the graduate studies committee.

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Masters
The master's minor requires a minimum of 6 credits in ESCI courses.

Doctoral
The doctoral minor requires a minimum of 12 credits in ESCI courses.
Twin Cities Campus
Earth Sciences Ph.D.
Department of Earth Sciences
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Earth Sciences, University of Minnesota, John T. Tate Hall-Suite 150, 116 Church St. SE, Minneapolis, MN 55455 (612-624-1333; fax: 612-625-3819)
Email: esci@umn.edu
Website: http://www.esci.umn.edu/programs/graduate

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 48
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The modern earth sciences are a remarkable synthesis of the physical and biological sciences. They are at the forefront of inquiry into and solutions of most of the major issues involving the global environment: climate, oceans, freshwater in all its forms, natural resources, and natural disasters. Like no other field, they integrate all the systems, from surface to great depth, from physics to chemistry to biology, and over all of geologic time and all geographic scales. The program includes the fields of structural geology, tectonics, petrology, hydrogeology, geomorphology, sedimentology, surface processes, geochemistry, biogeochemistry, biogeology, chemical oceanography, mineralogy, mineral and rock magnetism, rock and mineral physics, geodynamics, seismology, geostatistics, planetary geology, and geophysics and applied geophysics.

Students may accommodate other areas of interest such as engineering geology, environmental geology, materials science, soil science, and paleoecology by choosing a minor or supporting field from outside the program.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

Bachelor's degree in geology, geophysics, earth and material sciences, chemistry, physics, biology, or environmental science.

Other requirements to be completed before admission:
At least one year of study each in calculus, chemistry, and physics is required. In general, an outstanding academic record is expected.

Special Application Requirements:
Materials required for a complete application file include the student's statement of purpose, three letters of recommendation, transcripts, official GRE scores, and the Application for Admission. Applications are considered at any time; however, to be considered for financial aid, all materials must be submitted by December 15. Studies may begin in any semester or summer session, although fall semester is preferable. IMPORTANT: Refer to the Graduate Programs section of the department website (http://www.esci.umn.edu/programs/gradprospective) for a listing of all required application materials and preferred method of submission.

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
12 credits are required in the major.
12 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.0 is required for students to remain in good standing.

At the onset of studies, a coursework "compact" will be developed with the student, his/her advisor, and the graduate studies committee. The compact will be reviewed annually to assure timely progress and revise as needed.

Students must choose one of five tracks in the earth sciences program: geology, geophysics, biogeology, hydrogeology, or earth sciences. Tracks carry coursework requirements that are part of the student's course compact.

The PhD requires a minimum 12 credits of coursework in earth sciences, including the track requirements, a minimum of 12 credits in a minor or supporting field, plus 24 thesis credits.

A maximum of 9 credits of 4xxx-level coursework may be used towards programs requirements. Coursework taken A/F must be completed with an average grade of B or better.

Required Courses
All students must complete ESCI 8001, preferably in the first year.

**ESCI 8001** - Introductory Graduate Seminar (2.0 cr)

**Minor or Supporting Program Coursework**
Take 12 credits in a minor or in supporting fields outside ESCI.

**Thesis Credits**
Take 24 credits after passing preliminary oral exam

**ESCI 8888** - Thesis Credit: Doctoral (1.0 - 24.0 cr)

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

**Biogeology**
Biogeology represents a rapidly growing area at the intersection between Earth and the life sciences. It includes research in microbial evolution and biochemistry, microbe/mineral chemical interactions, the role of organisms in basic geological processes, the principles through which organisms or organic compounds can be used to reconstruct surface conditions, biogeochemical cycling, pollution control and remediation, the origin of life on Earth, and astrobiology. This is a broad field that is moving in new and exciting directions, and witnessing explosive growth in understanding the variety of ways biology mediates geology and vice versa. Many of the most basic earth surface processes are now seen as intimately biological with rates and pathways dictated by organic processes. Understanding the importance of these processes, quantifying them through time and place, and learning to utilize and/or control them will be major components of earth sciences research in the 21st century.

**Required Courses**
Take 6 or more credit(s) from the following:

- ESCI 8402 - Biogeochemical Cycles in the Ocean (3.0 cr)
- ESCI 8801 - Geomicrobiology (3.0 cr)

**Earth Sciences**

This generalist track exists for students whose curriculum and/or thesis (paper or project for MS Plan B) do not fit any of the other four tracks. Because it is not specific to a discipline, there are no mandatory courses in the major apart from the introductory graduate seminar, a minimum of 6 additional graduate-level credits in the major program, 12 supporting program credits or completion of all requirements for a minor, and thesis credits. A curriculum specific to the student will be set through the compact process.

6-credit minimum; courses determined on an individual basis.

**Geology**

Geology uses field observation, laboratory work, analog and computer modeling, chemical and biological probes and assays to understand Earth’s coupled rock, water and biological systems, the underlying processes, and their history of interaction as evidenced in the rock record.

**Required Courses**

Take 6 or more credit(s) from the following:

- ESCI 5302 - Isotope Geology (3.0 cr)
- ESCI 5351 - Geochemical Modeling of Aqueous Systems (3.0 cr)
- ESCI 5353 - Electron Microprobe Theory and Practice (3.0 cr)
- ESCI 5502 - Advanced Structural Geology (3.0 cr)
- ESCI 5503 - Advanced Petrology (3.0 cr)
- ESCI 5601W - Advanced Sedimentology [WI] (4.0 cr)
- ESCI 5705 - Limnogeology and Paleoenvironment (3.0 cr)

**Geophysics**

Geophysics uses remote sensing probes (seismic waves, potential fields, etc.), laboratory simulation of deep Earth conditions and computer modeling of fluid and continuum mechanical dynamics to investigate the structure, composition, history and dynamics of solid Earth and other planets.

**Required Courses**

ESCI 4211 - Solid Earth Geophysics I (3.0 cr)

Take 1 or more course(s) totaling 3 or more credit(s) from the following:

- ESCI 4212 - Solid Earth Geophysics II (3.0 cr)
- ESCI 5201 - Time-Series Analysis of Geological Phenomena (3.0 cr)
- ESCI 5203 - Mineral and Rock Physics (3.0 cr)
- ESCI 5204 - Geostatistics and Inverse Theory (3.0 cr)
- ESCI 8203 - Environmental Geophysics (3.0 cr)
- ESCI 8204 - Geomagnetism and Paleomagnetism (3.0 cr)

**Hydrogeology**

Hydrogeology uses direct observation and remote sensing, computer modeling and laboratory simulation to constrain the interaction of water and rock in Earth’s shallow subsurface. Freshwater is Earth’s most precious and increasingly overexploited resource. Hydrogeology is a key discipline in the effective shepherding of this important reserve. This track establishes a baseline curriculum for hydrogeology at the graduate level. The compact process will identify additional coursework appropriate to the student’s prior training and research directions.

**Required Courses**

ESCI 4702 - General Hydrogeology (4.0 cr)

Take 1 or more course(s) totaling 3 or more credit(s) from the following:

- ESCI 5205 - Fluid Mechanics in Earth and Environmental Sciences (3.0 cr)
- ESCI 5971 - Field Hydrogeology (2.0 cr)
Twin Cities Campus
Electrical Engineering M.S.E.E.
Electrical and Computer Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Director of Graduate Studies, Department of Electrical and Computer Engineering, University of Minnesota, 3-166 Keller Hall, 200 Union Street SE, Minneapolis, MN 55455 (612-625-3564; fax: 612-626-1136).
Email: jager001@umn.edu
Website: http://www.ece.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Science in Electrical Engineering

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The Department of Electrical and Computer Engineering offers diverse educational programs that encompass nearly all aspects of modern electrical and computer engineering, ranging from the very theoretical system and information theory to highly experimental work in novel device research and microelectronics. Emphases in the major are solid state and physical electronics, surface physics, thin films, sputtering, noise and fluctuation phenomena, quantum electronics, plasma physics, automation, power systems and power electronics theory, wave propagation, communication systems and theory, optics, lasers, fiber optics, magnetism, semiconductor properties and devices, VLSI and WSI engineering in theory and practice, network theory, signal and image processing, and computer and systems engineering. Interdisciplinary work is also available in bioelectrical sciences, control sciences, computer sciences, solar energy, applications of systems theory to urban transportation and economic planning, and biological modeling.

Students are considered for admission beginning fall semester only (except for part-time students living in Minnesota who work in industry and who may apply for other terms). The deadline for applying for fall semester is December 1.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)
• completely online (all program coursework can be completed online)
• primarily online (at least 80% of the instruction for the program is online with short, intensive periods of face-to-face coursework)
• partially online (between 50% to 80% of instruction is online)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.40.

Other requirements to be completed before admission:
Consideration is given to students who have completed another curriculum in engineering, science, physics, or mathematics that includes sufficient preparation to pursue a graduate program in electrical engineering. In some instances, additional preparatory studies may be required after admission.

All documents must be submitted electronically. No documents should be mailed to the department or the Graduate Admissions Office.

Every applicant must submit the General Test of the GRE (except University of Minnesota bachelor of electrical engineering graduates who have a GPA of 3.40 or better). The GRE Subject Test is not required for admission.

Special Application Requirements:
Applications are accepted for fall admission only. The deadline is December 1. Additional application information is available at http://www.ece.umn.edu/ProspectiveStudentsGraduate/index.htm

Applicants must submit their test score(s) from the following:
• GRE
International applicants must submit score(s) from one of the following tests:

- **TOEFL**
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550

- **IELTS**
  - Total Score: 6.5

- **MELAB**
  - Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

### Program Requirements

**Plan A:** Plan A requires 14 major credits, 6 credits outside the major, and 10 thesis credits. The final exam is oral.

**Plan C:** Plan C requires 18 to 24 major credits and 6 to 12 credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

The MSEE requires a minimum of 30 credits. Plan A requires 14 credits in EE courses, 6 credits in a minor or in related fields outside of the department, and 10 thesis credits. Plan C requires at least 18 credits from EE courses 5xxx and above, at least 6 credits in a minor or in related fields outside of the department, and additional credits from the major or related fields to meet the 30-credit minimum. Courses taken outside of the major field must be within the College of Science and Engineering.

Part-time students must choose Plan C; full-time students may choose either Plan A or Plan C. The department limits project, seminar, special investigation, directed study credits, and GRAD 999 registrations.

All courses must be taken A-F, with the exception of EE 5041, EE 8925, and graduate seminars, which are only offered S-N. Cross-listed courses must be taken under the EE designator to count towards degree requirements. Non-EE coursework that is cross-listed with Electrical Engineering does not count toward the non-EE coursework requirement.

A maximum of nine 4xxx-level course credits may be used to satisfy masters degree requirements; of these, only six credits may be in EE courses. Only the 4xxx-level courses included on the lists below will be accepted.

M.S.E.E. students who wish to pursue the PhD must pass the PhD preliminary written examination by the end of their second year in residence. Students have two chances to pass the examination. The PhD preliminary written examination is typically held in November and in April.

### Coursework

**Major Coursework**

Courses from this list can be applied to both Plan A and Plan C major field credit requirements. Plan C students can also apply these courses toward MSEE's 30-credit minimum.

- **EE 5121** - Transistor Device Modeling for Circuit Simulation (3.0 cr)
- **EE 5141** - Introduction to Microsystem Technology (4.0 cr)
- **EE 5163** - Semiconductor Properties and Devices I (3.0 cr)
- **EE 5164** - Semiconductor Properties and Devices II (3.0 cr)
- **EE 5171** - Microelectronic Fabrication (4.0 cr)
- **EE 5173** - Basic Microelectronics Laboratory (1.0 cr)
- **EE 5181** - Micro and Nanotechnology by Self Assembly (3.0 cr)
- **EE 5231** - Linear Systems and Optimal Control (3.0 cr)
- **EE 5235** - Robust Control System Design (3.0 cr)
- **EE 5239** - Introduction to Nonlinear Optimization (3.0 cr)
- **EE 5251** - Optimal Filtering and Estimation (3.0 cr)
- **EE 5301** - VLSI Design Automation I (3.0 cr)
EE 5302 - VLSI Design Automation II (3.0 cr)
EE 5323 - VLSI Design I (3.0 cr)
EE 5324 - VLSI Design II (3.0 cr)
EE 5327 - VLSI Design Laboratory (3.0 cr)
EE 5329 - VLSI Digital Signal Processing Systems (3.0 cr)
EE 5333 - Analog Integrated Circuit Design (3.0 cr)
EE 5351 - Applied Parallel Programming (3.0 cr)
EE 5364 - Advanced Computer Architecture (3.0 cr)
EE 5371 - Computer Systems Performance Measurement and Evaluation (3.0 cr)
EE 5381 - Telecommunications Networks (3.0 cr)
EE 5391 - Computing With Neural Networks (3.0 cr)
EE 5393 - Circuits, Computation, and Biology (3.0 cr)
EE 5501 - Digital Communication (3.0 cr)
EE 5505 - Wireless Communication (3.0 cr)
EE 5531 - Probability and Stochastic Processes (3.0 cr)
EE 5542 - Adaptive Digital Signal Processing (3.0 cr)
EE 5545 - Digital Signal Processing Structures for VLSI (3.0 cr)
EE 5549 - Multiscale and Multirate Signal Processing (3.0 cr)
EE 5551 - Information Theory and Coding (3.0 cr)
EE 5553 - Error Control Coding (3.0 cr)
EE 5555 - Data Compression (3.0 cr)
EE 5601 - Introduction to RF/Microwave Engineering (3.0 cr)
EE 5602 - RF/Microwave Circuit Design (3.0 cr)
EE 5611 - Plasma-Aided Manufacturing (4.0 cr)
EE 5613 - RF/Microwave Circuit Design Laboratory (2.0 cr)
EE 5616 - Antenna Theory and Design (3.0 cr)
EE 5621 - Physical Optics (3.0 cr)
EE 5622 - Physical Optics Laboratory (1.0 cr)
EE 5624 - Optical Electronics (4.0 cr)
EE 5627 - Optical Fiber Communication (3.0 cr)
EE 5628 - Fiber Optics Laboratory (1.0 cr)
EE 5629 - Optical System Design (2.0 cr)
EE 5653 - Physical Principles of Magnetic Materials (3.0 cr)
EE 5655 - Magnetic Recording (3.0 cr)
EE 5657 - Physical Principles of Thin Film Technology (4.0 cr)
EE 5705 - Electric Drives in Sustainable Energy Systems (3.0 cr)
EE 5707 - Electric Drives in Sustainable Energy Systems Laboratory (1.0 cr)
EE 5721 - Power Generation Operation and Control (3.0 cr)
EE 5725 - Power Systems Engineering (3.0 cr)
EE 5741 - Advanced Power Electronics (3.0 cr)
EE 5745 - Wind Energy Essentials (2.0 cr)
EE 5940 - Special Topics in Electrical Engineering I (1.0 - 4.0 cr)
EE 5950 - Special Topics in Electrical Engineering II (1.0 - 4.0 cr)
EE 5960 - Special Topics in Electrical Engineering III (1.0 - 4.0 cr)
EE 5970 - Special Topics in Electrical Engineering IV (1.0 - 4.0 cr)
EE 8141 - Advanced Heterojunction Transistors (3.0 cr)
EE 8161 - Physics of Semiconductors (3.0 cr)
EE 8163 - Quantum Electronics (3.0 cr)
EE 8213 - Advanced System Theory (3.0 cr)
EE 8215 - Nonlinear Systems (3.0 cr)
EE 8231 - Optimization Theory (3.0 cr)
EE 8235 - Advanced Control Topics (3.0 cr)
EE 8300 - Advanced Topics in Computers (1.0 - 3.0 cr)
EE 8310 - Advanced Topics in VLSI (1.0 - 3.0 cr)
EE 8320 - Advanced Topics in Design Automation (1.0 - 3.0 cr)
EE 8331 - CMOS Data Converters: A/D and D/A (3.0 cr)
EE 8337 - Analog Circuits for Wire/Wireless Communications (3.0 cr)
EE 8367 - Parallel Computer Organization (3.0 cr)
EE 8510 - Advanced Topics in Communications (1.0 - 3.0 cr)
EE 8520 - Advanced Topics in Signal Processing (1.0 - 3.0 cr)
EE 8581 - Detection and Estimation Theory (3.0 cr)
EE 8591 - Predictive Learning from Data (3.0 cr)
Outside Coursework
Courses from this list can be applied to both the Plan A and Plan C outside (non-EE) credit requirements. Plan C students can also apply these courses toward MSEEs 30-credit minimum.

AEM 4203 - Aerospace Propulsion (4.0 cr)
AEM 4295 - Problems in Fluid Mechanics (1.0 - 3.0 cr)
AEM 4301 - Orbital Mechanics (3.0 cr)
AEM 4303W - Flight Dynamics and Control [WI] (3.0 cr)
AEM 4305 - Spacecraft Attitude Dynamics and Control (3.0 cr)
AEM 4331 - Aerospace Vehicle Design (4.0 cr)
AEM 4333 - Aerospace Design: Special Projects (3.0 cr)
AEM 4495 - Problems in Aerospace Systems (3.0 cr)
AEM 4501 - Aerospace Structures (3.0 cr)
AEM 4502 - Computational Structural Analysis (3.0 cr)
AEM 4511 - Mechanics of Composite Materials (3.0 cr)
AEM 4581 - Mechanics of Solids (3.0 cr)
AEM 4595 - Problems in Mechanics and Materials (1.0 - 3.0 cr)
AEM 4601 - Instrumentation Laboratory (3.0 cr)
AEM 4602W - Aeromechanics Laboratory [WI] (4.0 cr)
AEM 5247 - Hypersonic Aerodynamics (3.0 cr)
AEM 5253 - Computational Fluid Mechanics (3.0 cr)
AEM 5333 - Design-to-Flight: Small Uninhabited Aerial Vehicles (3.0 cr)
AEM 5401 - Intermediate Dynamics (3.0 cr)
AEM 5501 - Continuum Mechanics (3.0 cr)
AEM 5503 - Theory of Elasticity (3.0 cr)
AEM 5581 - Mechanics of Solids (3.0 cr)
AEM 5651 - Aeroelasticity (3.0 cr)
BBE 4023 - Process Control and Instrumentation (3.0 cr)
BBE 5333 - Off-road Vehicle Design (4.0 cr)
SSM 5413 - A Systems Approach to Residential Construction (4.0 cr)
SSM 5416 - Building Testing & Diagnostics (2.0 cr)
BBE 5733 - Renewable Energy Technologies (3.0 cr)
BIOC 5361 - Microbial Genomics and Bioinformatics (3.0 cr)
BIOC 5527 - Introduction to Modern Structural Biology (4.0 cr)
BIOC 5528 - Spectroscopy and Kinetics (4.0 cr)
BIOL 4003 - Genetics (3.0 cr)
BIOL 4004 - Cell Biology (3.0 cr)
PMB 4121 - Microbial Ecology and Applied Microbiology (3.0 cr)
BIOL 4850 - Special Topics in Biology (1.0 - 5.0 cr)
BIOL 5272 - Applied Biostatistics (4.0 cr)
BMEN 5001 - Advanced Biomaterials (3.0 cr)
BMEN 5041 - Tissue Engineering (3.0 cr)
BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
BMEN 5111 - Biomedical Ultrasound (3.0 cr)
BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
BMEN 5201 - Advanced Biomechanics (3.0 cr)
BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
BMEN 5321 - Microfluidics in Biology and Medicine (3.0 cr)
BMEN 5351 - Cell Engineering (3.0 cr)
BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
BMEN 5411 - Neural Engineering (3.0 cr)
BMEN 5412 - Neuromodulation (3.0 cr)
BMEN 5413 - Neural Decoding and Interfacing (3.0 cr)
BMEN 5421 - Introduction to Biomedical Optics (3.0 cr)
BMEN 5501 - Biology for Biomedical Engineers (3.0 cr)
BMEN 5701 - Cancer Bioengineering (3.0 cr)
CEGE 5211 - Traffic Engineering (3.0 cr)
CEGE 5411 - Applied Structural Mechanics (3.0 cr)
CHEM 4001 - Chemistry of Biomass and Biomass Conversion to Fuels and Products (4.0 cr)
CHEM 4011 - Mechanisms of Chemical Reactions (3.0 cr)
CHEM 4021 - Computational Chemistry (3.0 cr)
CHEM 4066 - Chemistry of Industry (3.0 cr)
CHEM 4101 - Modern Instrumental Methods of Chemical Analysis (3.0 cr)
CHEM 4111W - Modern Instrumental Methods of Chemical Analysis Lab [WI] (2.0 cr)
CHEM 4201 - Materials Chemistry (3.0 cr)
CHEM 4214 - Polymers (3.0 cr)
CHEM 4221 - Introduction to Polymer Chemistry (3.0 cr)
CHEM 4233W - Polymer Laboratory [WI] (2.0 cr)
CHEM 4301 - Applied Surface and Colloid Science (3.0 cr)
CHEM 4311W - Advanced Organic Chemistry Lab [WI] (4.0 cr)
CHEM 4321 - Organic Synthesis (3.0 cr)
CHEM 4322 - Advanced Organic Chemistry (3.0 cr)
CHEM 4352 - Physical Organic Chemistry (3.0 cr)
CHEM 4361 - Interpretation of Organic Spectra (3.0 cr)
CHEM 4411 - Introduction to Chemical Biology (3.0 cr)
CHEM 4412 - Chemical Biology of Enzymes (3.0 cr)
CHEM 4501 - Introduction to Thermodynamics, Kinetics, and Statistical Mechanics (3.0 cr)
CHEM 4502 - Introduction to Quantum Mechanics and Spectroscopy (3.0 cr)
CHEM 4511W - Advanced Physical Chemistry Lab [WI] (3.0 cr)
CHEM 4601 - Green Chemistry [ENV] (3.0 cr)
CHEM 4701 - Inorganic Chemistry (3.0 cr)
CHEM 4711W - Advanced Inorganic Chemistry Lab [WI] (3.0 cr)
CHEM 4715 - Physical Inorganic Chemistry (3.0 cr)
CHEM 4725 - Organometallic Chemistry (3.0 cr)
CHEM 4735 - Bioinorganic Chemistry (3.0 cr)
CHEM 4745 - Advanced Inorganic Chemistry (3.0 cr)
CHEM 5755 - X-Ray Crystallography (4.0 cr)
CHEN 4214 - Polymers (3.0 cr)
CHEN 4401W - Senior Chemical Engineering Lab [WI] (3.0 cr)
CHEN 4501W - Chemical Engineering Design I [WI] (3.0 cr)
CHEN 4502W - Chemical Engineering Design II [WI] (2.0 cr)
CHEN 4601 - Process Control (3.0 cr)
CHEN 4701 - Applied Math (3.0 cr)
CHEN 4702 - Advanced Undergraduate Rheology (2.0 cr)
CHEN 4704 - Advanced Undergraduate Physical Rate Processes I: Transport (3.0 cr)
CHEN 4707 - Advanced Undergraduate Statistical Thermodynamics and Kinetics (3.0 cr)
CHEN 4708 - Advanced Undergraduate Chemical Rate Processes: Analysis of Chemical Reactors (3.0 cr)
CHEN 5751 - Biochemical Engineering (3.0 cr)
CHEN 5753 - Advanced Biomedical Transport Processes (3.0 cr)
CHEN 5771 - Colloids and Dispersions (3.0 cr)
CMB 5200 - Statistical Genetics and Genomics (4.0 cr)
CSCI 4011 - Formal Languages and Automata Theory (4.0 cr)
CSCI 4041 - Algorithms and Data Structures (4.0 cr)
CSCI 4041H - Algorithms and Data Structures (4.0 cr)
CSCI 4061 - Introduction to Operating Systems (4.0 cr)
CSCI 4131 - Internet Programming (3.0 cr)
CSCI 4211 - Introduction to Computer Networks (3.0 cr)
CSCI 4511W - Introduction to Artificial Intelligence [WI] (4.0 cr)
CSCI 4611 - Programming Interactive Computer Graphics and Games (3.0 cr)
CSCI 4707 - Practice of Database Systems (3.0 cr)
CSCI 4921 - History of Computing [TS, HIS] (3.0 cr)
CSCI 4970W - Advanced Project Laboratory [WI] (3.0 cr)
CSCI 5103 - Operating Systems (3.0 cr)
CSCI 5105 - Introduction to Distributed Systems (3.0 cr)
CSCI 5106 - Programming Languages (3.0 cr)
CSCI 5115 - User Interface Design, Implementation and Evaluation (3.0 cr)
CSCI 5125 - Collaborative and Social Computing (3.0 cr)
CSCI 5143 - Real-Time and Embedded Systems (3.0 cr)
CSCI 5161 - Introduction to Compilers (3.0 cr)
CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
CSCI 5221 - Foundations of Advanced Networking (3.0 cr)
CSCI 5231 - Wireless and Sensor Networks (3.0 cr)
CSCI 5271 - Introduction to Computer Security (3.0 cr)
CSCI 5302 - Analysis of Numerical Algorithms (3.0 cr)

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSCI 5304</td>
<td>Computational Aspects of Matrix Theory</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5403</td>
<td>Computational Complexity</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5421</td>
<td>Advanced Algorithms and Data Structures</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5451</td>
<td>Introduction to Parallel Computing: Architectures, Algorithms, and Programming</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5461</td>
<td>Functional Genomics, Systems Biology, and Bioinformatics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5471</td>
<td>Modern Cryptography</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5481</td>
<td>Computational Techniques for Genomics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5511</td>
<td>Artificial Intelligence I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5512</td>
<td>Artificial Intelligence II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5521</td>
<td>Introduction to Machine Learning</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5522</td>
<td>Introduction to Data Mining</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5525</td>
<td>Machine Learning</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5551</td>
<td>Introduction to Intelligent Robotic Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5552</td>
<td>Sensing and Estimation in Robotics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5561</td>
<td>Computer Vision</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5607</td>
<td>Fundamentals of Computer Graphics 1</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5608</td>
<td>Fundamentals of Computer Graphics II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5609</td>
<td>Visualization</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5611</td>
<td>Animation &amp; Planning in Games</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5619</td>
<td>Virtual Reality and 3D Interaction</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5707</td>
<td>Principles of Database Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5708</td>
<td>Architecture and Implementation of Database Management Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5801</td>
<td>Software Engineering I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5802</td>
<td>Software Engineering II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>ESOI 5201</td>
<td>Time-Series Analysis of Geological Phenomena</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>ESOI 5204</td>
<td>Geostatistics and Inverse Theory</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>ESOI 5205</td>
<td>Fluid Mechanics in Earth and Environmental Sciences</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>ESCI 5302</td>
<td>Isotope Geology</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>ESCI 5353</td>
<td>Electron Microprobe Theory and Practice</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>GCD 5036</td>
<td>Molecular Cell Biology</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>IE 5111</td>
<td>Systems Engineering I</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>IE 5113</td>
<td>Systems Engineering II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>IE 5441</td>
<td>Financial Decision Making</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4065</td>
<td>Theory of Interest</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4152</td>
<td>Elementary Mathematical Logic</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 4242</td>
<td>Applied Linear Algebra</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4281</td>
<td>Introduction to Modern Algebra</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4428</td>
<td>Mathematical Modeling</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4512</td>
<td>Differential Equations with Applications</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 4567</td>
<td>Applied Fourier Analysis</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4603</td>
<td>Advanced Calculus I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4604</td>
<td>Advanced Calculus II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4653</td>
<td>Elementary Probability</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4707</td>
<td>Introduction to Combinatorics and Graph Theory</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4990</td>
<td>Topics in Mathematics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5067</td>
<td>Actuarial Mathematics I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5068</td>
<td>Actuarial Mathematics II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5075</td>
<td>Mathematics of Options, Futures, and Derivative Securities I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5076</td>
<td>Mathematics of Options, Futures, and Derivative Securities II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5165</td>
<td>Mathematical Logic I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5166</td>
<td>Mathematical Logic II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5248</td>
<td>Cryptology and Number Theory</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5251</td>
<td>Error-Correcting Codes, Finite Fields, Algebraic Curves</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5335</td>
<td>Geometry I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5336</td>
<td>Geometry II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5378</td>
<td>Differential Geometry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5385</td>
<td>Introduction to Computational Algebraic Geometry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5445</td>
<td>Mathematical Analysis of Biological Networks</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5447</td>
<td>Theoretical Neuroscience</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5467</td>
<td>Introduction to the Mathematics of Image and Data Analysis</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5485</td>
<td>Introduction to Numerical Methods I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5486</td>
<td>Introduction To Numerical Methods II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5525</td>
<td>Introduction to Ordinary Differential Equations</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5535</td>
<td>Dynamical Systems and Chaos</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5583</td>
<td>Complex Analysis</td>
<td>4.0 cr</td>
</tr>
</tbody>
</table>
Plan A

Plan A students have the option to apply the following courses to their major field credit requirement. A maximum of 2 credits from the following subset of this list can be used: EE 8190, EE 8210, EE 8230, EE 8360, EE 8370, EE 8500, EE 8610, EE 8660, EE 8820, EE 8925, EE 8940.

- EE 4111 - Advanced Analog Electronics Design (4.0 cr)
- EE 4161W - Energy Conversion and Storage [WI] (3.0 cr)
- EE 4163 - Energy Conversion and Storage Laboratory (1.0 cr)
- EE 4231 - Linear Control Systems: Designed by Input/Output Methods (3.0 cr)
- EE 4233 - State Space Control System Design (3.0 cr)
- EE 4235 - Linear Control Systems Laboratory (1.0 cr)
- EE 4237 - State Space Control Laboratory (1.0 cr)
- EE 4301 - Digital Design With Programmable Logic (4.0 cr)
- EE 4303 - Introduction to Programmable Devices Laboratory (1.0 cr)
- EE 4341 - Embedded System Design (4.0 cr)
- EE 4363 - Computer Architecture and Machine Organization (4.0 cr)
- EE 4389W - Introduction to Predictive Learning [WI] (3.0 cr)
- EE 4501 - Communications Systems (3.0 cr)
- EE 4505 - Communications Systems Laboratory (1.0 cr)
- EE 4541 - Digital Signal Processing (3.0 cr)
- EE 4607 - Wireless Hardware System Design (3.0 cr)
- EE 4701 - Electric Drives (3.0 cr)
- EE 4703 - Electric Drives Laboratory (1.0 cr)
- EE 4721 - Introduction to Power System Analysis (3.0 cr)
- EE 4722 - Power System Analysis Laboratory (1.0 cr)
- EE 4741 - Power Electronics (3.0 cr)
- EE 4743 - Switch-Mode Power Electronics Laboratory (1.0 cr)
- EE 5041 - Industrial Assignment for Graduate Students (1.0 cr)
- EE 8190 - Electronics Seminar (1.0 cr)
- EE 8210 - System Theory Seminar (1.0 cr)
- EE 8230 - Control Theory Seminar (1.0 cr)
- EE 8360 - Computer Systems Seminar (1.0 cr)
- EE 8370 - Computer Aided Design Seminar (1.0 cr)
- EE 8500 - Seminar: Communications (1.0 cr)
- EE 8610 - Seminar: Electronics, Fields, and Photonics (1.0 cr)
- EE 8660 - Seminar: Magnetics (1.0 cr)
- EE 8920 - Teaching Experience in Electrical and Computer Engineering (1.0 cr)
- EE 8925 - Ethics in Electrical and Computer Engineering (1.0 cr)
- EE 8940 - Special Investigations (1.0 - 3.0 cr)

Thesis Credits

All Plan A students must take at least 10 master's thesis credits.

- EE 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Plan C

Plan C students have the option to apply the following courses toward MSEEs 30-credit minimum. These courses do not satisfy the major or outside (non-EE) credit requirements.

A maximum of 2 credits of the following may be applied: EE 5041, EE 8190, EE 8210, EE 8230, EE 8360, EE 8370, EE 8500, EE 8610, EE 8660, EE 8920, EE 8925, and EE 8940.

- EE 4111 - Advanced Analog Electronics Design (4.0 cr)
- EE 4161W - Energy Conversion and Storage [WI] (3.0 cr)
- EE 4163 - Energy Conversion and Storage Laboratory (1.0 cr)
- EE 4231 - Linear Control Systems: Designed by Input/Output Methods (3.0 cr)
- EE 4233 - State Space Control System Design (3.0 cr)
- EE 4235 - Linear Control Systems Laboratory (1.0 cr)
- EE 4237 - State Space Control Laboratory (1.0 cr)
- EE 4301 - Digital Design With Programmable Logic (4.0 cr)
- EE 4303 - Introduction to Programmable Devices Laboratory (1.0 cr)
- EE 4341 - Embedded System Design (4.0 cr)
- EE 4363 - Computer Architecture and Machine Organization (4.0 cr)
EE 4389W - Introduction to Predictive Learning [WI] (3.0 cr)
EE 4501 - Communications Systems (3.0 cr)
EE 4505 - Communications Systems Laboratory (1.0 cr)
EE 4541 - Digital Signal Processing (3.0 cr)
EE 4607 - Wireless Hardware System Design (3.0 cr)
EE 4701 - Electric Drives (3.0 cr)
EE 4703 - Electric Drives Laboratory (1.0 cr)
EE 4721 - Introduction to Power System Analysis (3.0 cr)
EE 4722 - Power System Analysis Laboratory (1.0 cr)
EE 4741 - Power Electronics (3.0 cr)
EE 4743 - Switch-Mode Power Electronics Laboratory (1.0 cr)
EE 5041 - Industrial Assignment for Graduate Students (1.0 cr)
EE 8190 - Electronics Seminar (1.0 cr)
EE 8210 - System Theory Seminar (1.0 cr)
EE 8230 - Control Theory Seminar (1.0 cr)
EE 8360 - Computer Systems Seminar (1.0 cr)
EE 8370 - Computer Aided Design Seminar (1.0 cr)
EE 8500 - Seminar: Communications (1.0 cr)
EE 8610 - Seminar: Electronics, Fields, and Photonics (1.0 cr)
EE 8660 - Seminar: Magnetics (1.0 cr)
EE 8920 - Teaching Experience in Electrical and Computer Engineering (1.0 cr)
EE 8925 - Ethics in Electrical and Computer Engineering (1.0 cr)
EE 8940 - Special Investigations (1.0 - 3.0 cr)

Project Requirement
Plan C students must complete a paper and project. The following courses satisfy all or a portion of the requirement. Contact the EE department for additional information.

EE 5171 - Microelectronic Fabrication (4.0 cr)
EE 5235 - Robust Control System Design (3.0 cr)
EE 5301 - VLSI Design Automation I (3.0 cr)
EE 5324 - VLSI Design II (3.0 cr)
EE 5327 - VLSI Design Laboratory (3.0 cr)
EE 5329 - VLSI Digital Signal Processing Systems (3.0 cr)
EE 5333 - Analog Integrated Circuit Design (3.0 cr)
EE 5364 - Advanced Computer Architecture (3.0 cr)
EE 5371 - Computer Systems Performance Measurement and Evaluation (3.0 cr)
EE 5505 - Wireless Communication (3.0 cr)
EE 5545 - Digital Signal Processing Design (3.0 cr)
EE 5601 - Introduction to RF/Microwave Engineering (3.0 cr)
EE 5602 - RF/Microwave Circuit Design (3.0 cr)
EE 5611 - Plasma-Aided Manufacturing (4.0 cr)
EE 5613 - RF/Microwave Circuit Design Laboratory (2.0 cr)
EE 5621 - Physical Optics (3.0 cr)
EE 5624 - Optical Electronics (4.0 cr)
EE 5627 - Optical Fiber Communication (3.0 cr)
EE 5653 - Physical Principles of Magnetic Materials (3.0 cr)
EE 5655 - Magnetic Recording (3.0 cr)
EE 5657 - Physical Principles of Thin Film Technology (4.0 cr)
EE 5725 - Power Systems Engineering (3.0 cr)
EE 8161 - Physics of Semiconductors (3.0 cr)
EE 8337 - Analog Circuits for Wire/Wireless Communications (3.0 cr)
EE 8591 - Predictive Learning from Data (3.0 cr)
EE 8611 - Plasma Physics (3.0 cr)
EE 8965 - Plan C Project I (3.0 cr)
EE 8967 - Plan C Project II (1.0 - 3.0 cr)

Program Sub-plans
A sub-plan is not required for this program.

Students may not complete the program with more than one sub-plan.

Rochester
The University of Minnesota Rochester (UMR) offers the MS degree in electrical engineering. Students may complete all degree requirements in Rochester by combining courses taught by College of Science and Engineering faculty in person (face-to-face), or via streaming video using the UNITE (University-Industry Television for Education) instructional television system. UNITE enables students
to watch class live via the internet or pick up class on a special server at a later time.

**Integrated B.E.E./M.S.E.E.**
The Department of Electrical and Computer Engineering offers an integrated bachelor of electrical engineering (BEE) and master of science in electrical engineering (MSEE). The integrated BEE/MSEE program offers students the opportunity to earn both degrees in five years. The programs were established to allow high-achieving University undergraduates the opportunity to work toward a masters degree while simultaneously working toward their undergraduate degree. The combined program offers several advantages: flexibility in fulfilling required courses for both degrees during the senior year; eligibility for graduate assistantships and fellowships; and the ability to save money by completing up to 16 graduate credits at the undergraduate tuition rate.

Both the BEE and MSEE degrees must be completed in their entirety, with no courses shared between them. The graduate degree cannot be earned before the undergraduate requirements are satisfied.

Eligibility requirements:

Application to the integrated program is open to University students in the electrical engineering or computer engineering program who have completed a majority of the required upper division courses for their undergraduate degree and have a cumulative GPA of 3.4 or higher. Students with a GPA between 3.2 and 3.4 may also apply, but must submit a GRE score.

**Integrated B.Comp.E./M.S.E.E.**
The Department of Electrical and Computer Engineering offers an integrated bachelor of computer engineering (B.Comp.E.) and master of science in electrical engineering (MSEE). Benefits, eligibility requirements, and degree-completion requirements outlined for the BEEE/MSEE integrated program also apply to the B.Comp.E/MSEE.
**Twin Cities Campus**

**Electrical Engineering Minor**  
*Electrical and Computer Engineering*  
**College of Science and Engineering**

Link to a list of faculty for this program.

**Contact Information:**  
Director of Graduate Studies, Department of Electrical and Computer Engineering, University of Minnesota, 3-166 Keller Hall, 200 Union Street SE, Minneapolis, MN 55455 (612-625-3564; fax: 612-626-1136)  
Email: jager001@umn.edu  
Website: [http://www.ece.umn.edu](http://www.ece.umn.edu)

- Program Type: Graduate minor related to major  
- Requirements for this program are current for Fall 2018  
- Length of program in credits (Masters): 6  
- Length of program in credits (Doctorate): 12  
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The Department of Electrical and Computer Engineering offers diverse educational programs that encompass nearly all aspects of modern electrical and computer engineering, ranging from the very theoretical system and information theory, to highly experimental work in novel device research and microelectronics. Emphases in the major are solid state and physical electronics, surface physics, thin films, sputtering, noise and fluctuation phenomena, quantum electronics, plasma physics, automation, power systems and power electronics theory, wave propagation, communication systems and theory, optics, lasers, fiber optics, magnetism, semiconductor properties and devices, VLSI and VSI engineering in theory and practice, network theory, signal and image processing, and computer and systems engineering. Interdisciplinary work is also available in bioelectrical sciences, control sciences, computer sciences, solar energy, applications of systems theory to urban transportation and economic planning, and biological modeling.

**Program Delivery**  
This program is available:  
- via classroom (the majority of instruction is face-to-face)  
- partially online (between 50% to 80% of instruction is online)

**Prerequisites for Admission**  
The preferred undergraduate GPA for admittance to the program is 3.40.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

**Program Requirements**  
Use of 4xxx courses towards program requirements is not permitted.

Minor credits must be 5xxx or 8xxx level. Coursework must be from classroom and laboratory courses. No colloquia, seminar, or special investigation credits count toward meeting the minor requirements.

**Program Sub-plans**  
Students are required to complete one of the following sub-plans.  
Students may not complete the program with more than one sub-plan.

**Masters**  
The master's minor requires a minimum of 6 credits in EE courses. All courses must be taken A-F. Courses that are cross-listed must be taken under the EE designator to count towards degree requirements.
Doctoral
The doctoral minor requires a minimum of 12 credits in EE courses. All courses must be taken A-F. Courses that are cross-listed must be taken under the EE designator to count towards degree requirements.
Twin Cities Campus
Electrical Engineering Ph.D.
Electrical and Computer Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Director of Graduate Studies, Department of Electrical and Computer Engineering, University of Minnesota, 3-166 Keller Hall, 200 Union Street SE, Minneapolis, MN 55455 (612-625-3564; fax: 612-626-1136)
Email: jager001@umn.edu
Website: http://www.ece.umn.edu

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 64
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The Department of Electrical and Computer Engineering offers diverse educational programs that encompass nearly all aspects of modern electrical and computer engineering, ranging from the very theoretical system and information theory to highly experimental work in novel device research and microelectronics. Emphases in the major are solid state and physical electronics, surface physics, thin films, sputtering, noise and fluctuation phenomena, quantum electronics, plasma physics, automation, power systems and power electronics theory, wave propagation, communication systems and theory, optics, lasers, fiber optics, magnetism, semiconductor properties and devices, VLSI and WSI engineering in theory and practice, network theory, signal and image processing, and computer and systems engineering. Interdisciplinary work is also available in bioelectrical sciences, control sciences, computer sciences, solar energy, applications of systems theory to urban transportation and economic planning, and biological modeling.

Students are considered for admission beginning fall semester only (except for part-time students living in Minnesota who work in industry who may apply for other terms). The deadline for applying for fall semester is December 1.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)
• partially online (between 50% to 80% of instruction is online)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.40.

Other requirements to be completed before admission:
All documents must be submitted electronically. No documents should be mailed to the department or the Graduate Admissions Office.

Applicants to the doctoral program must submit a writing sample with their online application. The writing sample should consist of a minimum of one, to a maximum of three, class papers or publications.

Every applicant, except University of Minnesota bachelor of electrical engineering graduates who have a GPA of 3.40 or better, must submit the General Test of the GRE. The GRE Subject Test is not required for admission.

Special Application Requirements:
Applications are accepted for fall admission only. The deadline is December 1. Additional application information is available at http://www.ece.umn.edu/ProspectiveStudentsGraduate/index.htm

Applicants must submit their test score(s) from the following:
• GRE

International applicants must submit score(s) from one of the following tests:
• TOEFL
  - Internet Based - Total Score: 79
Program Requirements
14 to 28 credits are required in the major.
12 to 26 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.30 is required for students to remain in good standing.

The PhD degree requires a minimum of 40 course credits and 24 thesis credits. The program must include 14 credits in EE courses at the 5xxx-level and above, and 12 credits in a minor or supporting program outside of EE but within the College of Science and Engineering (CSE). The remaining 14 credits may be taken in the major field or in any supporting field within CSE.

All courses must be taken A-F, with the exception of EE 5041, EE 8925, and graduate seminars, which are only offered S-N. Courses that are cross-listed must be taken under the EE designator to count towards degree requirements, and non-EE coursework that is cross listed with EE does not count toward the outside field requirement.

A minimum of 6 course credits at the 8xxx-level must be included. Courses can be from the major or outside field; but seminars, directed study, and special investigations may not be used to satisfy this requirement.

A maximum of nine 4xxx-level course credits may be used toward degree requirements. Only the 4xxx-level courses included on the lists below will be accepted.

PhD students who enter the department with a MS degree in electrical engineering must pass the PhD Preliminary Written Examination by the end of their third semester in residence. Students who enter with an MS in another field, or students who enter with a bachelor's degree, have until the end of their second year in residence to pass the exam. Students have two chances to pass the exam. The exam is typically held in November and in April.

Required Courses
Major Field Coursework
Major field coursework is accepted from the following list only. Take 14 or more credit(s) from the following:

- EE 5121 - Transistor Device Modeling for Circuit Simulation (3.0 cr)
- EE 5141 - Introduction to Microsystem Technology (4.0 cr)
- EE 5163 - Semiconductor Properties and Devices I (3.0 cr)
- EE 5164 - Semiconductor Properties and Devices II (3.0 cr)
- EE 5171 - Microelectronic Fabrication (4.0 cr)
- EE 5173 - Basic Microelectronics Laboratory (1.0 cr)
- EE 5181 - Micro and Nanotechnology by Self Assembly (3.0 cr)
- EE 5231 - Linear Systems and Optimal Control (3.0 cr)
- EE 5235 - Robust Control System Design (3.0 cr)
- EE 5239 - Introduction to Nonlinear Optimization (3.0 cr)
- EE 5251 - Optimal Filtering and Estimation (3.0 cr)
- EE 5301 - VLSI Design Automation I (3.0 cr)
- EE 5302 - VLSI Design Automation II (3.0 cr)
- EE 5323 - VLSI Design I (3.0 cr)
- EE 5324 - VLSI Design II (3.0 cr)
- EE 5327 - VLSI Design Laboratory (3.0 cr)
• EE 5329 - VLSI Digital Signal Processing Systems (3.0 cr)
• EE 5333 - Analog Integrated Circuit Design (3.0 cr)
• EE 5351 - Applied Parallel Programming (3.0 cr)
• EE 5364 - Advanced Computer Architecture (3.0 cr)
• EE 5371 - Computer Systems Performance Measurement and Evaluation (3.0 cr)
• EE 5381 - Telecommunications Networks (3.0 cr)
• EE 5391 - Computing With Neural Networks (3.0 cr)
• EE 5393 - Circuits, Computation, and Biology (3.0 cr)
• EE 5501 - Digital Communication (3.0 cr)
• EE 5505 - Wireless Communication (3.0 cr)
• EE 5531 - Probability and Stochastic Processes (3.0 cr)
• EE 5542 - Adaptive Digital Signal Processing (3.0 cr)
• EE 5545 - Digital Signal Processing Design (3.0 cr)
• EE 5549 - Digital Signal Processing Structures for VLSI (3.0 cr)
• EE 5551 - Multiscale and Multirate Signal Processing (3.0 cr)
• EE 5561 - Image Processing and Applications (3.0 cr)
• EE 5581 - Information Theory and Coding (3.0 cr)
• EE 5583 - Error Control Coding (3.0 cr)
• EE 5585 - Data Compression (3.0 cr)
• EE 5601 - Introduction to RF/Microwave Engineering (3.0 cr)
• EE 5602 - RF/Microwave Circuit Design (3.0 cr)
• EE 5611 - Plasma-Aided Manufacturing (4.0 cr)
• EE 5613 - RF/Microwave Circuit Design Laboratory (2.0 cr)
• EE 5616 - Antenna Theory and Design (3.0 cr)
• EE 5621 - Physical Optics (3.0 cr)
• EE 5622 - Physical Optics Laboratory (1.0 cr)
• EE 5624 - Optical Electronics (4.0 cr)
• EE 5627 - Optical Fiber Communication (3.0 cr)
• EE 5628 - Fiber Optics Laboratory (1.0 cr)
• EE 5629 - Optical System Design (2.0 cr)
• EE 5653 - Physical Principles of Magnetic Materials (3.0 cr)
• EE 5655 - Magnetic Recording (3.0 cr)
• EE 5657 - Physical Principles of Thin Film Technology (4.0 cr)
• EE 5705 - Electric Drives in Sustainable Energy Systems (3.0 cr)
• EE 5707 - Electric Drives in Sustainable Energy Systems Laboratory (1.0 cr)
• EE 5721 - Power Generation Operation and Control (3.0 cr)
• EE 5725 - Power Systems Engineering (3.0 cr)
• EE 5741 - Advanced Power Electronics (3.0 cr)
• EE 5745 - Wind Energy Essentials (2.0 cr)
• EE 5940 - Special Topics in Electrical Engineering I (1.0 - 4.0 cr)
• EE 5950 - Special Topics in Electrical Engineering II (1.0 - 4.0 cr)
• EE 5960 - Special Topics in Electrical Engineering III (1.0 - 4.0 cr)
• EE 5970 - Special Topics in Electrical Engineering IV (1.0 - 4.0 cr)
• EE 8100 - Advanced Topics in Electronics (1.0 - 3.0 cr)
• EE 8141 - Advanced Heterojunction Transistors (3.0 cr)
• EE 8161 - Physics of Semiconductors (3.0 cr)
• EE 8163 - Quantum Electronics (3.0 cr)
• EE 8213 - Advanced System Theory (3.0 cr)
• EE 8215 - Nonlinear Systems (3.0 cr)
• EE 8231 - Optimization Theory (3.0 cr)
• EE 8235 - Advanced Control Topics (3.0 cr)
• EE 8300 - Advanced Topics in Computers (1.0 - 3.0 cr)
• EE 8310 - Advanced Topics in VLSI (1.0 - 3.0 cr)
• EE 8320 - Advanced Topics in Design Automation (1.0 - 3.0 cr)
• EE 8331 - CMOS Data Converters: A/D and D/A (3.0 cr)
• EE 8337 - Analog Circuits for Wire/Wireless Communications (3.0 cr)
• EE 8367 - Parallel Computer Organization (3.0 cr)
• EE 8510 - Advanced Topics in Communications (1.0 - 3.0 cr)
• EE 8520 - Advanced Topics in Signal Processing (1.0 - 3.0 cr)
• EE 8581 - Detection and Estimation Theory (3.0 cr)
• EE 8591 - Predictive Learning from Data (3.0 cr)
• EE 8601 - Advanced Electromagnetic Theory (3.0 cr)
• EE 8611 - Plasma Physics (3.0 cr)
• EE 8620 - Advanced Topics in Magnetics (1.0 - 3.0 cr)
• EE 8630 - Advanced Topics in Electromagnetics (1.0 - 3.0 cr)
• EE 8725 - Advanced Power System Analysis and Economics (3.0 cr)
• EE 8741 - Power Electronics in Power Systems (3.0 cr)
• EE 8950 - Advanced Topics in Electrical and Computer Engineering (1.0 - 3.0 cr)

Outside Field Coursework
Outside field and the additional coursework credits may be chosen from this list. A maximum of 2 credits of the following may be applied: EE 5041, EE 8190, EE 8210, EE 8230, EE 8360, EE 8370, EE 8500, EE 8610, EE 8660, EE 8920, EE 8925, and EE 8940. Take 12 or more credit(s) from the following:
• AEM 4203 - Aerospace Propulsion (4.0 cr)
• AEM 4295 - Problems in Fluid Mechanics (1.0 - 3.0 cr)
• AEM 4301 - Orbital Mechanics (3.0 cr)
• AEM 4303W - Flight Dynamics and Control [WI] (3.0 cr)
• AEM 4305 - Spacecraft Attitude Dynamics and Control (3.0 cr)
• AEM 4331 - Aerospace Vehicle Design (4.0 cr)
• AEM 4333 - Aerospace Design: Special Projects (3.0 cr)
• AEM 4495 - Problems in Aerospace Systems (3.0 cr)
• AEM 4501 - Aerospace Structures (3.0 cr)
• AEM 4502 - Computational Structural Analysis (3.0 cr)
• AEM 4511 - Mechanics of Composite Materials (3.0 cr)
• AEM 4581 - Mechanics of Solids (3.0 cr)
• AEM 4595 - Problems in Mechanics and Materials (1.0 - 3.0 cr)
• AEM 4601 - Instrumentation Laboratory (3.0 cr)
• AEM 4602W - Aeromechanics Laboratory [WI] (4.0 cr)
• AEM 5247 - Hypersonic Aerodynamics (3.0 cr)
• AEM 5253 - Computational Fluid Mechanics (3.0 cr)
• AEM 5333 - Design-to-Flight: Small Uninhabited Aerial Vehicles (3.0 cr)
• AEM 5401 - Intermediate Dynamics (3.0 cr)
• AEM 5501 - Continuum Mechanics (3.0 cr)
• AEM 5503 - Theory of Elasticity (3.0 cr)
• AEM 5581 - Mechanics of Solids (3.0 cr)
• AEM 6551 - Aeroelasticity (3.0 cr)
• AEM 8202 - Fluid Mechanics II (3.0 cr)
• AEM 8211 - Theory of Turbulence I (3.0 cr)
• AEM 8253 - Computational Methods in Fluid Mechanics (3.0 cr)
• AEM 8421 - Robust Multivariable Control Design (3.0 cr)
• AEM 8423 - Convex Optimization Methods in Control (3.0 cr)
• AEM 8495 - Advanced Topics in Aerospace Systems (1.0 - 4.0 cr)
• AEM 9023 - Process Control and Instrumentation (3.0 cr)
• BBE 5333 - Off-road Vehicle Design (4.0 cr)
• BSM 5413 - A Systems Approach to Residential Construction (4.0 cr)
• BSM 5416 - Building Testing & Diagnostics (2.0 cr)
• BBE 5733 - Renewable Energy Technologies (3.0 cr)
• BIOC 5361 - Microbial Genomics and Bioinformatics (3.0 cr)
• BIOC 5527 - Introduction to Modern Structural Biology (4.0 cr)
• BIOC 5528 - Spectroscopy and Kinetics (4.0 cr)
• BIOL 4003 - Genetics (3.0 cr)
• BIOL 4004 - Cell Biology (3.0 cr)
• PMB 4121 - Microbial Ecology and Applied Microbiology (3.0 cr)
• BIOL 4850 - Special Topics in Biology (1.0 - 5.0 cr)
• BIOL 5272 - Applied Biostatistics (4.0 cr)
• BMEN 5001 - Advanced Biomaterials (3.0 cr)
• BMEN 5041 - Tissue Engineering (3.0 cr)
• BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
• BMEN 5111 - Biomedical Ultrasound (3.0 cr)
• BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
• BMEN 5201 - Advanced Biomechanics (3.0 cr)
• BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
• BMEN 5321 - Microfluidics in Biology and Medicine (3.0 cr)
• BMEN 5351 - Cell Engineering (3.0 cr)
• BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
• BMEN 5411 - Neural Engineering (3.0 cr)
• BMEN 5412 - Neuromodulation (3.0 cr)
• BMEN 5413 - Neural Decoding and Interfacing (3.0 cr)
• BMEN 5421 - Introduction to Biomedical Optics (3.0 cr)
• BMEN 5501 - Biology for Biomedical Engineers (3.0 cr)
• BMEN 5701 - Cancer Bioengineering (3.0 cr)
• BMEN 8001 - Polymeric Biomaterials (3.0 cr)
• BMEN 8041 - Advanced Tissue Engineering Lab (3.0 cr)
• BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
• BMEN 8201 - Advanced Tissue Mechanics (3.0 cr)
• BMEN 8361 - Bioheat and Mass Transfer (3.0 cr)
• BMEN 8401 - New Product Design and Business Development (4.0 cr)
• BMEN 8402 - New Product Design and Business Development (4.0 cr)
• BMEN 8421 - Biophotonics (3.0 cr)
• BMEN 8501 - Dynamical Systems in Biology (3.0 cr)
• BMEN 8502 - Physiological Control Systems (3.0 cr)
• BMEN 8511 - Systems and Synthetic Biology (3.0 cr)
• BMEN 8900 - Special Topics in Biomedical Engineering (1.0 - 4.0 cr)
• CEGE 5211 - Traffic Engineering (3.0 cr)
• CEGE 5411 - Applied Structural Mechanics (3.0 cr)
• CHEM 4001 - Chemistry of Biomass and Biomass Conversion to Fuels and Products (4.0 cr)
• CHEM 4011 - Mechanisms of Chemical Reactions (3.0 cr)
• CHEM 4021 - Computational Chemistry (3.0 cr)
• CHEM 4066 - Chemistry of Industry (3.0 cr)
• CHEM 4101 - Modern Instrumental Methods of Chemical Analysis (3.0 cr)
• CHEM 4111W - Modern Instrumental Methods of Chemical Analysis Lab [WI] (2.0 cr)
• CHEM 4201 - Materials Chemistry (3.0 cr)
• CHEM 4214 - Polymers (3.0 cr)
• CHEM 4221 - Introduction to Polymer Chemistry (3.0 cr)
• CHEM 4223W - Polymer Laboratory [WI] (2.0 cr)
• CHEM 4301 - Applied Surface and Colloid Science (3.0 cr)
• CHEM 4311W - Advanced Organic Chemistry Lab [WI] (4.0 cr)
• CHEM 4321 - Organic Synthesis (3.0 cr)
• CHEM 4322 - Advanced Organic Chemistry (3.0 cr)
• CHEM 4352 - Physical Organic Chemistry (3.0 cr)
• CHEM 4361 - Interpretation of Organic Spectra (3.0 cr)
• CHEM 4411 - Introduction to Chemical Biology (3.0 cr)
• CHEM 4412 - Chemical Biology of Enzymes (3.0 cr)
• CHEM 4501 - Introduction to Thermodynamics, Kinetics, and Statistical Mechanics (3.0 cr)
• CHEM 4502 - Introduction to Quantum Mechanics and Spectroscopy (3.0 cr)
• CHEM 4511W - Advanced Physical Chemistry Lab [WI] (3.0 cr)
• CHEM 4601 - Green Chemistry [ENV] (3.0 cr)
• CHEM 4701 - Inorganic Chemistry (3.0 cr)
• CHEM 4711W - Advanced Inorganic Chemistry Lab [WI] (3.0 cr)
• CHEM 4715 - Physical Inorganic Chemistry (3.0 cr)
• CHEM 4725 - Organometallic Chemistry (3.0 cr)
• CHEM 4735 - Bioinorganic Chemistry (3.0 cr)
• CHEM 4745 - Advanced Inorganic Chemistry (3.0 cr)
• CHEM 5755 - X-Ray Crystallography (4.0 cr)
• CHEM 8152 - Analytical Spectroscopy (4.0 cr)
• CHEM 8201 - Materials Chemistry (4.0 cr)
• CHEM 8551 - Quantum Mechanics I (4.0 cr)
• CHEM 8552 - Quantum Mechanics II (4.0 cr)
• CHEN 4214 - Polymers (3.0 cr)
• CHEN 4401W - Senior Chemical Engineering Lab [WI] (3.0 cr)
• CHEN 4501W - Chemical Engineering Design I [WI] (3.0 cr)
• CHEN 4502W - Chemical Engineering Design II [WI] (2.0 cr)
• CHEN 4601 - Process Control (3.0 cr)
• CHEN 4701 - Applied Math (3.0 cr)
• CHEN 4702 - Advanced Undergraduate Rheology (2.0 cr)
• CHEN 4704 - Advanced Undergraduate Physical Rate Processes I: Transport (3.0 cr)
• CHEN 4707 - Advanced Undergraduate Statistical Thermodynamics and Kinetics (3.0 cr)
• CHEN 4708 - Advanced Undergraduate Chemical Rate Processes: Analysis of Chemical Reactors (3.0 cr)
• CHEN 5751 - Biochemical Engineering (3.0 cr)
• CHEN 5753 - Advanced Biomedical Transport Processes (3.0 cr)
• CHEN 5771 - Colloids and Dispersions (3.0 cr)
• CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
• CHEN 8401 - Physical and Chemical Thermodynamics (3.0 cr)
• CMB 8754 - Systems Analysis of Biological Processes (3.0 cr)
• CMB 8200 - Statistical Genetics and Genomics (4.0 cr)
• CSCI 4011 - Formal Languages and Automata Theory (4.0 cr)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSCI 4041</td>
<td>Algorithms and Data Structures</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CSCI 4041H</td>
<td>Algorithms and Data Structures</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CSCI 4061</td>
<td>Introduction to Operating Systems</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CSCI 4131</td>
<td>Internet Programming</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 4111</td>
<td>Introduction to Computer Networks</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 4511W</td>
<td>Introduction to Artificial Intelligence [WI]</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CSCI 4611</td>
<td>Programming Interactive Computer Graphics and Games</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 4707</td>
<td>Practice of Database Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 4921</td>
<td>History of Computing [TS, HIS]</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 4970W</td>
<td>Advanced Project Laboratory [WI]</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5103</td>
<td>Operating Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5105</td>
<td>Introduction to Distributed Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5115</td>
<td>User Interface Design, Implementation and Evaluation</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5125</td>
<td>Collaborative and Social Computing</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5143</td>
<td>Real-Time and Embedded Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5161</td>
<td>Introduction to Compilers</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5211</td>
<td>Data Communications and Computer Networks</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5221</td>
<td>Foundations of Advanced Networking</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5231</td>
<td>Wireless and Sensor Networks</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5271</td>
<td>Introduction to Computer Security</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5302</td>
<td>Analysis of Numerical Algorithms</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5304</td>
<td>Computational Aspects of Matrix Theory</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5403</td>
<td>Computational Complexity</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5421</td>
<td>Advanced Algorithms and Data Structures</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5451</td>
<td>Introduction to Parallel Computing: Architectures, Algorithms, and Programming</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5461</td>
<td>Functional Genomics, Systems Biology, and Bioinformatics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5471</td>
<td>Modern Cryptography</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5481</td>
<td>Computational Techniques for Genomics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5511</td>
<td>Artificial Intelligence I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5512</td>
<td>Artificial Intelligence II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5521</td>
<td>Introduction to Machine Learning</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5523</td>
<td>Introduction to Data Mining</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5525</td>
<td>Machine Learning</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5551</td>
<td>Introduction to Intelligent Robotic Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5552</td>
<td>Sensing and Estimation in Robotics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5561</td>
<td>Computer Vision</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5607</td>
<td>Fundamentals of Computer Graphics 1</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5608</td>
<td>Fundamentals of Computer Graphics 2</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5609</td>
<td>Visualization</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5611</td>
<td>Animation &amp; Planning in Games</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5619</td>
<td>Virtual Reality and 3D Interaction</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5707</td>
<td>Principles of Database Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5708</td>
<td>Architecture and Implementation of Database Management Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5801</td>
<td>Software Engineering I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5802</td>
<td>Software Engineering II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5816</td>
<td>Advanced Compiler Techniques</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 8205</td>
<td>Parallel Computer Organization</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 8211</td>
<td>Advanced Computer Networks and Their Applications</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 8314</td>
<td>Sparse Matrix Computations</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 8363</td>
<td>Numerical Linear Algebra in Data Exploration</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 8980</td>
<td>Special Advanced Topics in Computer Science</td>
<td>1.0 - 3.0 cr</td>
</tr>
<tr>
<td>EE 4111</td>
<td>Advanced Analog Electronics Design</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 4161W</td>
<td>Energy Conversion and Storage [WI]</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 4163</td>
<td>Energy Conversion and Storage Laboratory</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>EE 4231</td>
<td>Linear Control Systems: Designed by Input/Output Methods</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 4233</td>
<td>State Space Control System Design</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 4235</td>
<td>Linear Control Systems Laboratory</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>EE 4237</td>
<td>State Space Control Laboratory</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>EE 4301</td>
<td>Digital Design With Programmable Logic</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 4303</td>
<td>Introduction to Programmable Devices Laboratory</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>EE 4341</td>
<td>Embedded System Design</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 4363</td>
<td>Computer Architecture and Machine Organization</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 4389W</td>
<td>Introduction to Predictive Learning [WI]</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 4501</td>
<td>Communications Systems</td>
<td>3.0 cr</td>
</tr>
</tbody>
</table>
• EE 4505 - Communications Systems Laboratory (1.0 cr)
• EE 4541 - Digital Signal Processing (3.0 cr)
• EE 4607 - Wireless Hardware System Design (3.0 cr)
• EE 4701 - Electric Drives (3.0 cr)
• EE 4703 - Electric Drives Laboratory (1.0 cr)
• EE 4721 - Introduction to Power System Analysis (3.0 cr)
• EE 4722 - Power System Analysis Laboratory (1.0 cr)
• EE 4741 - Power Electronics (3.0 cr)
• EE 4743 - Switch-Mode Power Electronics Laboratory (1.0 cr)
• EE 5041 - Industrial Assignment for Graduate Students (1.0 cr)
• EE 8190 - Electronics Seminar (1.0 cr)
• EE 8210 - System Theory Seminar (1.0 cr)
• EE 8230 - Control Theory Seminar (1.0 cr)
• EE 8360 - Computer Systems Seminar (1.0 cr)
• EE 8370 - Computer Aided Design Seminar (1.0 cr)
• EE 8600 - Seminar: Magnetics (1.0 cr)
• EE 8920 - Teaching Experience in Electrical and Computer Engineering (1.0 cr)
• EE 8925 - Ethics in Electrical and Computer Engineering (1.0 cr)
• EE 8940 - Special Investigations (1.0 - 3.0 cr)
• ESCI 5201 - Time-Series Analysis of Geological Phenomena (3.0 cr)
• ESCI 5204 - Geostatistics and Inverse Theory (3.0 cr)
• ESCI 5205 - Fluid Mechanics in Earth and Environmental Sciences (3.0 cr)
• ESCI 5302 - Isotope Geology (3.0 cr)
• ESCI 5353 - Electron Microprobe Theory and Practice (3.0 cr)
• GCD 5036 - Molecular Cell Biology (3.0 cr)
• IE 5111 - Systems Engineering I (2.0 cr)
• IE 5113 - Systems Engineering II (4.0 cr)
• IE 5441 - Financial Decision Making (4.0 cr)
• IE 8531 - Discrete Optimization (4.0 cr)
• IE 8532 - Stochastic Processes and Queuing Systems (4.0 cr)
• IE 8534 - Advanced Topics in Operations Research (4.0 cr)
• MATH 4065 - Theory of Interest (4.0 cr)
• MATH 4152 - Elementary Mathematical Logic (3.0 cr)
• MATH 4248 - Cryptology and Number Theory (4.0 cr)
• MATH 4335 - Geometry I (4.0 cr)
• MATH 4336 - Geometry II (4.0 cr)
• MATH 4378 - Differential Geometry (4.0 cr)
• MATH 4428 - Mathematical Modeling (4.0 cr)
• MATH 4512 - Differential Equations with Applications (3.0 cr)
• MATH 4567 - Applied Fourier Analysis (4.0 cr)
• MATH 4603 - Advanced Calculus I (4.0 cr)
• MATH 4604 - Advanced Calculus II (4.0 cr)
• MATH 4653 - Elementary Probability (4.0 cr)
• MATH 4707 - Introduction to Combinatorics and Graph Theory (4.0 cr)
• MATH 4990 - Topics in Mathematics (1.0 - 4.0 cr)
• MATH 5067 - Actuarial Mathematics I (4.0 cr)
• MATH 5068 - Actuarial Mathematics II (4.0 cr)
• MATH 5075 - Mathematics of Options, Futures, and Derivative Securities I (4.0 cr)
• MATH 5076 - Mathematics of Options, Futures, and Derivative Securities II (4.0 cr)
• MATH 5165 - Mathematical Logic I (4.0 cr)
• MATH 5166 - Mathematical Logic II (4.0 cr)
• MATH 5248 - Cryptology and Number Theory (4.0 cr)
• MATH 5251 - Error-Correcting Codes, Finite Fields, Algebraic Curves (4.0 cr)
• MATH 5335 - Geometry I (4.0 cr)
• MATH 5336 - Geometry II (4.0 cr)
• MATH 5378 - Differential Geometry (4.0 cr)
• MATH 5385 - Introduction to Computational Algebraic Geometry (4.0 cr)
• MATH 5445 - Mathematical Analysis of Biological Networks (4.0 cr)
• MATH 5447 - Theoretical Neuroscience (4.0 cr)
• MATH 5467 - Introduction to the Mathematics of Image and Data Analysis (4.0 cr)
• MATH 5485 - Introduction to Numerical Methods I (4.0 cr)
• MATH 5486 - Introduction To Numerical Methods II (4.0 cr)
• MATH 5525 - Introduction to Ordinary Differential Equations (4.0 cr)
• MATH 5535 - Dynamical Systems and Chaos (4.0 cr)
• MATH 5583 - Complex Analysis (4.0 cr)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 5587</td>
<td>Elementary Partial Differential Equations I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5588</td>
<td>Elementary Partial Differential Equations II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5651</td>
<td>Basic Theory of Probability and Statistics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5652</td>
<td>Introduction to Stochastic Processes</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5654</td>
<td>Prediction and Filtering</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5705</td>
<td>Enumerative Combinatorics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5707</td>
<td>Graph Theory and Non-enumerator Combinatorics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5711</td>
<td>Linear Programming and Combinatorial Optimization</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 8301</td>
<td>Manifolds and Topology</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8302</td>
<td>Manifolds and Topology</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8401</td>
<td>Mathematical Modeling and Methods of Applied Math</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8402</td>
<td>Mathematical Modeling and Methods of Applied Math</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8442</td>
<td>Numerical Analysis and Scientific Computing</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8445</td>
<td>Numerical Analysis of Differential Equations</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8450</td>
<td>Topics in Numerical Analysis</td>
<td>1.0 - 3.0 cr</td>
</tr>
<tr>
<td>MATH 8500</td>
<td>Topics in Advanced Applied Mathematics</td>
<td>1.0 - 3.0 cr</td>
</tr>
<tr>
<td>MATH 8601</td>
<td>Real Analysis</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8602</td>
<td>Real Analysis</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8651</td>
<td>Theory of Probability Including Measure Theory</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8668</td>
<td>Combinatorial Theory</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 5517</td>
<td>Electron Microscopy</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 5531</td>
<td>Electrochemical Engineering</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 5771</td>
<td>Colloids and Dispersions</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 8001</td>
<td>Structure and Symmetry of Materials</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 8003</td>
<td>Electronic Properties</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 8995</td>
<td>Special Topics</td>
<td>1.0 - 4.0 cr</td>
</tr>
<tr>
<td>ME 5113</td>
<td>Aerosol/Particle Engineering</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5223</td>
<td>Materials in Design</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5228</td>
<td>Introduction to Finite Element Modeling, Analysis, and Design</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5241</td>
<td>Computer-Aided Engineering</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5243</td>
<td>Advanced Mechanism Design</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5247</td>
<td>Stress Analysis, Sensing, and Transducers</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5281</td>
<td>Analog and Digital Control</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5286</td>
<td>Robotics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5312</td>
<td>Solar Thermal Technologies</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5344</td>
<td>Thermodynamics of Fluid Flow With Applications</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5351</td>
<td>Computational Heat Transfer</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5461</td>
<td>Internal Combustion Engines</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 8228</td>
<td>Finite Elements in Multidisciplinary Flow/Thermal/Stress and Manufacturing Applications</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 8229</td>
<td>Finite Element Methods for Computational Mechanics: Transient/Dynamic Problems</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 8243</td>
<td>Topics in Design</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 8253</td>
<td>Computational Nanomechanics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>ME 8254</td>
<td>Fundamentals of Microelectromechanical Systems (MEMS)</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 8281</td>
<td>Advanced Control System Design</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 8343</td>
<td>Radiation</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MOT 4001</td>
<td>Leadership, Professionalism and Business Basics</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>MPHY 5170</td>
<td>Basic Radiological Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MPHY 5171</td>
<td>Medical and Health Physics of Imaging I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MPHY 5174</td>
<td>Medical and Health Physics of Imaging II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MPHY 8147</td>
<td>Advanced Physics of Magnetic Resonance Imaging</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>NPSE 8101</td>
<td>Nanoparticle Science and Engineering Seminar</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>NSC 5040</td>
<td>Brain Networks: From Connectivity to Dynamics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>NSC 5202</td>
<td>Theoretical Neuroscience: Systems and Information Processing</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>NSC 5203</td>
<td>Basic and Clinical Vision Science</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>NSC 5561</td>
<td>Systems Neuroscience</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 5061</td>
<td>Principles of Physiology for Biomedical Engineering</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 5101</td>
<td>Human Physiology</td>
<td>5.0 cr</td>
</tr>
<tr>
<td>PHYS 5201</td>
<td>Computational Neuroscience I: Membranes and Channels</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 4001</td>
<td>Analytical Mechanics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 4002</td>
<td>Electricity and Magnetism</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 4041</td>
<td>Computational Methods in the Physical Sciences</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 4051</td>
<td>Methods of Experimental Physics I</td>
<td>5.0 cr</td>
</tr>
<tr>
<td>PHYS 4052W</td>
<td>Methods of Experimental Physics II [WI]</td>
<td>5.0 cr</td>
</tr>
<tr>
<td>PHYS 4101</td>
<td>Quantum Mechanics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 4121W</td>
<td>History of 20th-Century Physics [WI]</td>
<td>3.0 cr</td>
</tr>
</tbody>
</table>
PHYS 4201 - Statistical and Thermal Physics (3.0 cr)
PHYS 4211 - Introduction to Solid-State Physics (3.0 cr)
PHYS 4303 - Electrodynamics and Waves (3.0 cr)
PHYS 4511 - Introduction to Nuclear and Particle Physics (3.0 cr)
PHYS 4611 - Introduction to Space Physics (3.0 cr)
PHYS 4621 - Introduction to Plasma Physics (3.0 cr)
PHYS 4911 - Introduction to Biopolymer Physics (3.0 cr)
PHYS 5001 - Quantum Mechanics I (4.0 cr)
PHYS 5002 - Quantum Mechanics II (4.0 cr)
PHYS 5011 - Classical Physics I (4.0 cr)
PHYS 5012 - Classical Physics II (4.0 cr)
PHYS 5041 - Mathematical Methods for Physics (4.0 cr)
PHYS 5081 - Introduction to Biopolymer Physics (3.0 cr)
PHYS 5201 - Thermal and Statistical Physics (3.0 cr)
PHYS 5402 - Radiological Physics (4.0 cr)
PHYS 5701 - Solid-State Physics for Engineers and Scientists (4.0 cr)
PHYS 8001 - Advanced Quantum Mechanics (3.0 cr)
PHYS 8711 - Solid-State Physics I (3.0 cr)
PHYS 8712 - Solid-State Physics II (3.0 cr)
PSY 5036W - Computational Vision [WI] (3.0 cr)
PSY 5038W - Introduction to Neural Networks [WI] (3.0 cr)
STAT 4101 - Theory of Statistics I (4.0 cr)
STAT 4102 - Theory of Statistics II (4.0 cr)
STAT 5021 - Statistical Analysis (4.0 cr)
STAT 5031 - Statistical Methods for Quality Improvement (4.0 cr)
STAT 5101 - Theory of Statistics I (4.0 cr)
STAT 5102 - Theory of Statistics II (4.0 cr)
STAT 5201 - Sampling Methodology in Finite Populations (3.0 cr)
STAT 5302 - Applied Regression Analysis (4.0 cr)
STAT 5303 - Designing Experiments (4.0 cr)
STAT 5401 - Applied Multivariate Methods (3.0 cr)
STAT 5421 - Analysis of Categorical Data (3.0 cr)
STAT 5511 - Time Series Analysis (3.0 cr)
STAT 8053 - Applied Statistical Methods 3: Multivariate Analysis and Advanced Regression (3.0 cr)
STAT 8054 - Statistical Methods 4: Advanced Statistical Computing (3.0 cr)
STAT 8101 - Theory of Statistics I (3.0 cr)
STAT 8111 - Mathematical Statistics I (3.0 cr)
STAT 8501 - Introduction to Stochastic Processes with Applications (3.0 cr)
STAT 8711 - Statistical Computing (3.0 cr)
STAT 8931 - Advanced Topics in Statistics (3.0 cr)
STAT 8932 - Advanced Topics in Statistics (3.0 cr)

**Thesis Credits**
Take 24 credits after passing preliminary oral exam.

EE 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)
Twin Cities Campus
Environmental Restoration Engineering and Science M.S.
CSENG Civil, Envrn & Geo-Eng (CEGE)
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Environmental Restoration Engineering and Science Graduate Program, 122 Civil Engineering, 500 Pillsbury Drive SE, Minneapolis, MN 55455 (612-625-5522; fax: 612-626-7750)
Email: volle001@umn.edu
Website: http://www.cege.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program requires summer semesters for timely completion.
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

This program is not admitting students.

The goal of the master of science in environmental restoration engineering and science is to produce graduates who will understand how to combine engineering with physical, biological, and social sciences in order to contribute to the process of prioritizing, designing, implementing, evaluating, and setting policy for environmental restoration projects. In short, the program aims to generate future leaders who will both succeed in practice and set the national agenda for restoring, maintaining, and sustaining the Earth-surface environment.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A baccalaureate degree in a field related to ecology, civil engineering, or environmental and earth sciences. Other degrees will be accepted based on relevant experience at the discretion of the DGS.

Other requirements to be completed before admission:
This program is not admitting students.

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 16
  - Paper Based - Total Score: 550
- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.
Program Requirements

Plan C: Plan C requires 30 major credits and up to null credits outside the major. The is no final exam. A capstone project is required.

Capstone Project: Students complete the capstone project by undertaking a field research internship for 6 credits. Students will be required to document 100 hours of project-based work and will complement this work with a 10-minute oral presentation on the required Stream Restoration Practice course (CEGE 8602).

This program may not be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.0 is required for students to remain in good standing.

The program requires a minimum of 30 credits consisting of 9 credits in required core classes and 15 credits in elective courses chosen in consultation with advisor. The remaining 6 credits are met by undertaking a field-based internship.

Required Courses

- CEGE 8601 - Introduction to Stream Restoration (3.0 cr)
- CEGE 8602 - Stream Restoration Practice (2.0 cr)
- HORT 5071 - Ecological Restoration (4.0 cr)

Electives
Take at least 15 elective course credits, in consultation with the advisor.

Internship
Complete a 6-credit internship, in consultation with the advisor.
Environmental Restoration Engineering and Science Minor

CSENG Civil, Envrn & Geo-Eng (CEGE)

College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Environmental Restoration Science and Engineering Graduate Program, 122 Civil Engineering, 500 Pillsbury Dr SE, Minneapolis, MN 55455 (612-625-5522; fax: 612-626-7750)
Email: volle001@umn.edu
Website: http://www.cege.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 8
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The environmental restoration engineering and science minor is not currently admitting students.

The goal of the Environmental Restoration Engineering and Science program is to produce graduates who will understand how to combine engineering with physical, biological, and social sciences in order to contribute to the process of prioritizing, designing, implementing, evaluating, and setting policy for environmental restoration projects. In short, the program aims to generate future leaders who will both succeed in practice and set the national agenda for restoring, maintaining, and sustaining the Earth-surface environment.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

Other requirements to be completed before admission:
The environmental restoration engineering and science minor is not currently admitting students.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

The required courses, CEGE 8601 and CEGE 8602, are also offered as EEB/ESCI 8601 and EEB/ESCI 8602. Students obtaining a degree in earth sciences, civil engineering, or ecology, evolution and behavior should register for these courses under a designator other than their major field.

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Master's
Required Courses
CEGE 8601 - Introduction to Stream Restoration (3.0 cr)
CEGE 8602 - Stream Restoration Practice (2.0 cr)

**Recommended Elective**
Take at least 3 credits. Consult with the ERES director of graduate studies for other course options.

HORT 5071 - Ecological Restoration (4.0 cr)
Twin Cities Campus
Financial Mathematics M.F.M.
School of Mathematics
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Program in Financial Mathematics, 127 Vincent Hall, 206 Church Street SE, Minneapolis, MN 55455 (612-624-6391; fax: 612-624-6702)
Email: mfmath@umn.edu
Website: http://www.math.umn.edu/finmath/

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 32
- This program does not require summer semesters for timely completion.
- Degree: Master of Financial Mathematics

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The master of financial mathematics degree program helps students understand the underlying mathematics of quantitative finance. The program offers a range of courses, from theoretical to practical, including a mathematical course on stochastic processes, a practitioner's course offering hands-on application of financial software tools, and a programming course focusing on C# and MATLAB.

Courses are offered in the evenings to accommodate working professionals. The program is designed with the possibility for full-time students to complete all requirements in one year.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
A bachelor's degree from an accredited US university or foreign equivalent. The minimum undergraduate GPA for admittance to the program is 3.00.

Other requirements to be completed before admission:
Applicants should have completed college level courses in single variable and multivariable calculus and linear algebra. Background in probability and familiarity with programming language are highly recommended.

Special Application Requirements:
Applications are accepted for fall semester only. The application deadline is February 1. Additional information is available at math.umn.edu/mcfam/financial-mathematics.

Applicants must submit their test score(s) from the following:
• GRE

International applicants must submit score(s) from one of the following tests:
• TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19

Key to test abbreviations (GRE, TOEFL).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.
Program Requirements

**Plan C:** Plan C requires 32 major credits and up to null credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 2.80 is required for students to remain in good standing.

The MFM requires 32 credits, consisting of four year-long course sequences. These sequences may be taken either in parallel or sequentially, following their numerical order, with the exception of FM 5091/5092, which is recommended to be taken as early as possible. In addition to the 32 required credits, students who either do not have a strong mathematics background or who need a refresher may be asked to take FM 5001/5002 - Preparation for Financial Mathematics.

Students may take the optional FM 5990 topics course, which is offered periodically.

**Required Courses**
- FM 5011 - Mathematical Background for Finance I (4.0 cr)
- FM 5012 - Mathematical Background for Finance II (4.0 cr)
- FM 5021 - Mathematical Theory Applied to Finance I (4.0 cr)
- FM 5022 - Mathematical Theory Applied to Finance II (4.0 cr)
- FM 5031 - A Practitioner's Course in Finance I (4.0 cr)
- FM 5032 - A Practitioner's Course in Finance II (4.0 cr)
- FM 5091 - Computation, Algorithms, and Coding in Finance I (4.0 cr)
- FM 5092 - Computation, Algorithms, and Coding in Finance II (4.0 cr)

**Elective Course**
- FM 5990 - Topics in Financial Mathematics (1.0 - 2.0 cr)
Twin Cities Campus
Fundamentals of Quantitative Finance Postbaccalaureate Certificate
School of Mathematics
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Director of Graduate Studies, School of Mathematics, University of Minnesota, 127 Vincent Hall, 206 Church Street S.E., Minneapolis, MN 55455 (612-624-6391; fax: 612-624-6702)
Email: mfmath@umn.edu
Website: http://www.math.umn.edu

- Program Type: Post-baccalaureate credit certificate/licensure/endorsement
- Requirements for this program are current for Fall 2018
- Length of program in credits: 14
- This program does not require summer semesters for timely completion.
- Degree: Fundamentals of Quantitative Finance PBacc Cert

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The postbaccalaureate certificate in fundamentals of quantitative finance (FQF) is a 14-credit certificate with four required courses. The certificate is good preparation for the master of financial mathematics (M.F.M.) degree program.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)
- completely online (all program coursework can be completed online)

Prerequisites for Admission
A bachelor's degree from an accredited US university or foreign equivalent. The minimum undergraduate GPA for admittance to the program is 3.00.

Other requirements to be completed before admission:
Applicants should have a good background in mathematics, but not necessarily at the level of a mathematics major. In particular, all applicants must have taken at least three semesters of college calculus, covering two semesters of single variable calculus and an additional semester of either multivariable calculus or linear algebra.

Special Application Requirements:
Applications are accepted for fall semester only. The application deadline is May 15. Additional information is available at math.umn.edu/mcfam/financial-mathematics/fqf.

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19

Key to test abbreviations(TOEFL).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 2.80 is required for students to remain in good standing.
Students must complete four courses in financial mathematics for 14 credits.

**Required Courses**
- FM 5001 - Preparation for Financial Mathematics I (3.0 cr)
- FM 5002 - Preparation for Financial Mathematics II (3.0 cr)
- FM 5091 - Computation, Algorithms, and Coding in Finance I (4.0 cr)
- FM 5092 - Computation, Algorithms, and Coding in Finance II (4.0 cr)
Twin Cities Campus
Geoengineering M.GeoE.
CSENG Civil, Envrm & Geo-Eng (CEGE)
College of Science and Engineering

Contact Information:
Department of Civil, Environmental, and Geo-Engineering, University of Minnesota, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., Minneapolis, MN 55455 (612-625-5522; fax: 612-626-7750)
Email: cegesp@umn.edu
Website: http://www.cege.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Geoengineering

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Emphases are in fundamental aspects of geomechanics and its applications. Research focuses on the use and development of discrete and continuum theories such as elasticity, plasticity, fracture mechanics, and poroelasticity for solving engineering problems. Numerical methods are being developed for obtaining solutions; experimental methods and novel apparatus are being developed for gathering physical evidence. Applications include processes of comminution, flow of granular materials, hydraulic fracturing, and nondestructive testing.

The master of geoengineering (M.GeoE.) degree is for the practicing engineer who would like to obtain an advanced degree enrolling part-time or full-time. Students who intend to proceed to the PhD program, or who think they may later wish to be admitted to the PhD program, should apply for the master of science program. Students are expected to follow a coherent program of coursework selected with the help of a faculty advisor and approved by the director of graduate studies. Students also must demonstrate professional competence by carrying out and defending a design project or by taking a coursework-related final oral exam (without a project).

The degree typically takes 2-3 semesters (12-18 months) to complete on a full-time basis or 6-8 semesters on a part-time basis. Students interested in pursuing doctoral studies should see the PhD program in civil engineering.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

An ABET-accredited, four-year bachelor's degree in engineering is required for admission.

Other requirements to be completed before admission:
The application deadlines are December 3 for fall admission and August 31 for spring admission. All materials must be submitted to the online application. Additional information is available at http://www.cege.umn.edu/prospective/graduate/how-to-apply.html

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
- IELTS
  - Total Score: 6.5
- MELAB
Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

Plan A: Plan A requires 20 major credits, up to null credits outside the major, and 10 thesis credits. The final exam is oral.

Plan C: Plan C requires 30 major credits and up to null credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

The M.GeoE. requires a minimum of 30 credits and is offered under two plans. Plan A requires preparation of a thesis/design project. The thesis/design project must be carried out by the student in consultation with a faculty advisor. Plan C is a coursework-only degree program.

Required Courses

Any courses at the 5xxx and 8xxx level from the following programs may be used: AEM, AST, BBE, BMEN, CEGE, CHEM, CHEN, CSCI, EE, ESCI, IE, MATH, MATS, ME, PHYS, STAT. Use of 4xxx level courses must be approved by the director of graduate studies and a maximum of 9 credits may be included. The following 4xxx courses may not be used: CEGE 4121, 4311, 4501, and 4522. Six credits in a minor may be included in the course credit total.

Seminar

Students may count one seminar credit in the course credit total.

CEGE 8300 - Seminar: Geomechanics (1.0 - 3.0 cr)

Plan A

Plan A requires a minimum of 20 course credits and 10 thesis credits for the design project.

CEGE 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Plan C

Plan C requires 30 course credits and must include at least two courses at the 8xxx level. Students must also complete 100 hours of project work, give an oral presentation of no less than 10 minutes, and complete two hours of ethics training.
Twin Cities Campus
Geoengineering M.S.
CSENG Civil, Envirn & Geo-Eng (CEGE)
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Civil, Environmental, and Geo-Engineering, University of Minnesota, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., Minneapolis, MN 55455 (612-625-5522; fax: 612-626-7750)
Email: cegesps@umn.edu
Website: http://www.cege.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Emphases are in fundamental aspects of geomechanics and its applications. Research focuses on the use and development of discrete and continuum theories such as elasticity, plasticity, fracture mechanics, and poroelasticity for solving engineering problems. Numerical methods are being developed for obtaining solutions; experimental methods and novel apparatus are being developed for gathering physical evidence. Applications include processes of communication, flow of granular materials, hydraulic fracturing, and nondestructive testing.

The master of science (MS) degree balances education in engineering fundamentals and design with research and development. It is designed for students wishing to pursue a career in industry or to continue toward a PhD.

Students interested in pursuing doctoral studies should see the PhD program in civil engineering.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A bachelor's degree in engineering, basic science, or mathematics is preferred.

Other requirements to be completed before admission:
Admission depends primarily on the applicant's academic record and letters of recommendation. Applicants who lack geoengineering training are often required to complete at least one appropriate course from the undergraduate program. Graduate degree credit is not awarded for such preparatory work.

Special Application Requirements:
The application deadlines are December 3 for fall admission and August 31 for spring admission. All materials must be submitted to the online application. Additional information is available at http://www.cege.umn.edu/prospective/graduate/how-to-apply.html

Applicants must submit their test score(s) from the following:
• GRE

International applicants must submit score(s) from one of the following tests:
• TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
IELTS
- Total Score: 6.5
MELAB
- Final score: 80

Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

**Program Requirements**

**Plan A:** Plan A requires 20 major credits, up to null credits outside the major, and 10 thesis credits. The final exam is oral.

**Plan B:** Plan B requires 30 major credits and up to null credits outside the major. The final exam is oral.

**Plan C:** Plan C requires 30 major credits and up to null credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

The MS requires at least 30 credits and is offered under three plans. Plan A emphasizes research and preparation of a thesis; Plan B emphasizes coursework and a project; Plan C is coursework only. The Plan A thesis is written on a research project carried out in consultation with a faculty advisor. Under Plan B, students complete one to three Plan B papers as determined by the faculty advisor. Plan B papers can include computer programs, annotated bibliographies, field investigations, and analysis/design of special engineering problems. A program typically takes 18 to 24 months to complete.

**Required Courses**

Any courses at the 5xxx and 8xxx level from the following programs may be used: AEM, AST, BBE, BMEN, CEGE, CHEM, CHEN, CSCI, EE, ESCI, IE, MATH, MATS, ME, PHYS, STAT. Use of 4xxx level courses must be approved by the director of graduate studies and a maximum of 9 credits may be included. The following 4xxx courses may not be used: CEGE 4121, 4311, 4501, and 4522. Six credits in a minor may be included in the course credit total.

**Seminar**

Students may include one seminar credit in the course credit total

CEGE 8300 - Seminar: Geomechanics (1.0 - 3.0 cr)

**Plan A**

Plan A requires a minimum of 20 course credits and 10 thesis credits.

CEGE 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

**Plan B**

Plan B requires a minimum of 30 credits, which includes at least 27 course credits and a maximum of 3 credits of CEGE 8094 for the Plan B project.

CEGE 8094 - Civil Engineering Research (1.0 - 4.0 cr)

**Plan C**

Plan C requires 30 course credits and must include at least two courses at the 8xxx level. Students must also complete 100 hours of project work, give an oral presentation of no less than 10 minutes, and complete two hours of ethics training.

**Program Sub-plans**

A sub-plan is not required for this program.

Students may not complete the program with more than one sub-plan.

**Integrated B.GeoE./M.S. - Geoengineering**

The department offers an integrated Bachelor of Geoengineering (B.GeoE.) and master of science (MS) in geoengineering. The integrated B.GeoE./MS program offers students the opportunity to earn the bachelors and masters degree in five years. These programs offer several benefits: streamlined admissions from the undergraduate to the graduate program (GRE not required); flexibility
in fulfilling required courses for both degrees during the senior year (up to 16 credits can be transferred to the graduate program); and eligibility for teaching and research assistantships.

Both the B.GeoE. and MS degrees must be completed in their entirety, with no courses shared between them. The graduate degree cannot be earned before the undergraduate requirements are satisfied. Admitted students who decide not to complete the MS degree are permitted to count credits originally planned for the graduate program toward their B.GeoE. technical electives.

Eligibility Requirements

Application to the combined program is open to geoengineering undergraduates who:

- Are within 32 credits of completing the requirements for the bachelors degree;
- Have a faculty advisor selected prior to admission; and
- Hold a cumulative GPA of 3.3 or higher.

Integrated B.C.E./M.S. - Geoengineering

The department offers an integrated bachelor of civil engineering (B.C.E) and master of science (MS) in geoengineering. Benefits, eligibility requirements, and degree-completion requirements outlined for the B.GeoE./MS integrated program also apply to the B.C.E./MS.

Integrated B.Env.E./M.S. - Geoengineering

The department offers an integrated bachelor of environmental engineering (B.Env.E.) and master of science (MS) in geoengineering. Benefits, eligibility requirements, and degree-completion requirements outlined for the B.GeoE./MS integrated program also apply to the B.Env.E./MS.
Twin Cities Campus

Geoengineering Minor
CSENG Civil, Envrn & Geo-Eng (CEGE)

College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Civil, Environmental, and Geo-Engineering, University of Minnesota, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., Minneapolis, MN 55455 (612-625-5522; fax: 612-626-7750)
Email: cgeesps@umn.edu
Website: http://www.cege.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Emphases are in fundamental aspects of geomechanics and its applications. Research focuses on the use and development of discrete and continuum theories such as elasticity, plasticity, fracture mechanics, and poroelasticity for solving engineering problems. Numerical methods are being developed for obtaining solutions; experimental methods and novel apparatus are being developed for gathering physical evidence. Applications include processes of comminution, flow of granular materials, hydraulic fracturing, and nondestructive testing.

Program Delivery
This program is available:

- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Masters
For a master's minor, two or more 5xxx or 8xxx level courses in geoengineering are required, for a total of 6 or more credits.

Geoengineering
CEGE 53xx
CEGE 83xx
Twin Cities Campus
Industrial and Systems Engineering M.S.I.S.Y.E.
Industrial and Systems Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Industrial and Systems Engineering Graduate Program, University of Minnesota, 1120 Mechanical Engineering, 111 Church Street S.E., Minneapolis, MN 55455 (612-625-2009; fax 612-624-2010)
Email: gradinfo@ie.umn.edu
Website: http://www.ie.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30 to 32
- This program does not require summer semesters for timely completion.
- Degree: Master of Science in Industrial & Systems Engr

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The industrial and systems engineering (ISyE) program offers coursework and research in industrial and systems engineering, operations research, and human factors. Special emphasis is on methodologies for design, planning, and management of service and manufacturing systems. Examples of research applications include logistics, transportation, healthcare delivery systems, revenue management, and supply chain management.

The Department of Industrial & Systems Engineering offers an MS degree with three tracks the Industrial Engineering track, the Systems Engineering track, and the Analytics track and a PhD degree. MS degree applicants must indicate which track they are applying for on the application form. Note that the admission requirements for the three tracks are different. In addition, the ISyE program also offers a dual MS in ISyE and Civil Engineering (Transportation Engineering focus) and an integrated bachelor's/master's program.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A baccalaureate degree in engineering or a closely related field is required.

Other requirements to be completed before admission:
Applicants to the systems engineering track are required to have at least two years of professional work experience in a technical field. Promising candidates with less experience will be considered under exceptional circumstances. Applicants must submit three letters of recommendation and a personal statement. In addition to the academic record, the professional record of the applicant and the letters of recommendation carry weight in admission decisions. A GRE score is not required.

Special Application Requirements:
All application materials should be submitted electronically through the ApplyYourself application system.

Applicants to the industrial engineering and analytics tracks must submit a GRE score. Letters of recommendation are not required, but are highly recommended if you want to be considered for financial aid.

Applications for the analytics track are accepted for fall semester only.

The application deadlines are February 15 for fall semester and October 15 for spring semester. Additional information is available at www.isye.umn.edu/apply/
Applicants must submit their test score(s) from the following:
• GRE

International applicants must submit score(s) from one of the following tests:
• TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
• IELTS
  - Total Score: 6.5

Key to test abbreviations (GRE, TOEFL, IELTS).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

### Program Requirements

**Plan A:** Plan A requires 14 major credits, 6 credits outside the major, and 10 thesis credits. The final exam is oral.

**Plan B:** Plan B requires 16 to 24 major credits and 6 to 14 credits outside the major. The final exam is oral.

**Plan C:** Plan C requires 16 to 26 major credits and 6 to 16 credits outside the major. The is no final exam.

This program may be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

The Master of Science in Industrial and Systems Engineering (M.S.I.Sy.E.) is offered with three tracks.

The industrial engineering track has three options. Plan A (thesis) and Plan B (project) require 30 credits and Plan C (coursework) requires 32 credits. Plan A requires a minimum of 14 course credits in the major field, and Plan B or Plan C requires 16 course credits in the major field. All plans must include a minimum of 6 course credits in a minor or related field outside ISyE and 1 credit of graduate seminar. The remaining credits may be taken in the major field or any supporting field.

The systems engineering track is a coursework-only option (Plan C) requiring 30 credits. It requires a minimum of 14 course credits in the major field and 6 course credits in a minor or related field outside ISyE. The remaining 10 credits may be taken in the major or in any supporting field.

The analytics track is a coursework-only option (Plan C) requiring 30-32 credits. Students proceed through the program and advance as a cohort. The program requires 24 credits in core courses and a minimum of 6 credits in elective courses. In addition, non-native English speakers are required to take the 2-credit course ESL 5008.

Students may replace a required course with a qualifying replacement course if they have taken the equivalent of the required course elsewhere. A list of qualifying replacements is available on the ISyE program web page.

**Joint- or Dual-degree Coursework:** Dual M.S. in ISyE and Civil Engineering (Transportation Engineering Focus): Student may take a total of 15 credits in common among the academic programs.

### Program Sub-plans

Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

**Industrial Engineering**

**Plan A**

- **Required Courses**
  - IE 5531 - Engineering Optimization I (4.0 cr)
  - IE 5532 - Stochastic Models (4.0 cr)
ME 8001 - Research Ethics and Professional Practice (0.0 cr)
Take 1 or more course(s) from the following:
- IE 5511 - Human Factors and Work Analysis (4.0 cr)
- IE 5545 - Decision Analysis (4.0 cr)
- IE 5551 - Production Planning and Inventory Control (4.0 cr)

Seminar
Take 1 seminar credit. The following may be used or consult with advisor for further options.
- IE 8773 - Graduate Seminar (1.0 cr)
  or IE 8774 - Graduate Seminar (1.0 cr)

Thesis Credits
Take 10 credits
- IE 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Plan B or Plan C

Required Courses
- IE 5531 - Engineering Optimization I (4.0 cr)
- IE 5532 - Stochastic Models (4.0 cr)
- ME 8001 - Research Ethics and Professional Practice (0.0 cr)
Take 2 or more course(s) from the following:
- IE 5511 - Human Factors and Work Analysis (4.0 cr)
- IE 5545 - Decision Analysis (4.0 cr)
- IE 5551 - Production Planning and Inventory Control (4.0 cr)

Seminar
Take 1 seminar credit. The following may be used or consult with advisor for further options.
- IE 8773 - Graduate Seminar (1.0 cr)
  or IE 8774 - Graduate Seminar (1.0 cr)

Project Requirement
Plan B students must either take the Plan B courses IE 8951/8953 (3 credits), or complete one to three Plan B papers, determined in consultation with the advisor.
- IE 8951 - Plan B Course (1.0 cr)
- IE 8953 - Plan B (2.0 cr)

Systems Engineering
This sub-plan is limited to students completing the program under Plan C.

Required Courses
- IE 5111 - Systems Engineering I (2.0 cr)
- IE 5113 - Systems Engineering II (4.0 cr)
- IE 5541 - Project Management (4.0 cr)
- IE 5553 - Simulation (4.0 cr)
- ME 8001 - Research Ethics and Professional Practice (0.0 cr)

Analytics
This sub-plan is limited to students completing the program under Plan C.

Required Courses
- IE 5531 - Engineering Optimization I (4.0 cr)
- IE 5532 - Stochastic Models (4.0 cr)
- IE 5561 - Analytics and Data-Driven Decision Making (4.0 cr)
- IE 5773 - Practice-focused Seminar (1.0 cr)
- IE 5801 - Capstone Project (4.0 cr)
- STAT 5302 - Applied Regression Analysis (4.0 cr)
- CSCI 5521 - Introduction to Machine Learning (3.0 cr)
  or CSCI 5523 - Introduction to Data Mining (3.0 cr)

Electives
Additional courses may be approved by the Director of Graduate Studies.
Take 6 or more credit(s) from the following:
- IE 5441 - Financial Decision Making (4.0 cr)
- IE 5522 - Quality Engineering and Reliability (4.0 cr)
- IE 5541 - Project Management (4.0 cr)
- IE 5545 - Decision Analysis (4.0 cr)
- IE 5551 - Production Planning and Inventory Control (4.0 cr)
- IE 5553 - Simulation (4.0 cr)
- CSCI 5521 - Introduction to Machine Learning (3.0 cr)
• CSCI 5523 - Introduction to Data Mining (3.0 cr)

**English Proficiency**

Non-native English speakers are required to take the following:

ESL 5008 - Speaking for Professional Settings (2.0 cr)

**Integrated B.M.E./M.S.I.SY.E.**

This sub-plan is optional and does not fulfill the sub-plan requirement for this program.

The Department of Industrial and Systems Engineering and the Department of Mechanical Engineering offer an integrated bachelor's/master's degree program. The program makes it possible for students to earn a bachelor's degree in Mechanical Engineering (B.M.E.) and a master's degree in Industrial & Systems Engineering (M.S.I.SY.E.) in five years. The program has several benefits: a streamlined admissions process from the ME undergraduate program to the ISyE graduate program; graduate student status granted in the senior year; eligibility for teaching and research assistantships; and, flexibility in fulfilling required courses for both degrees simultaneously in the last two years of study. The integrated program is available only for the Industrial Engineering Track.

Both the BME and MSISYE degrees must be completed in their entirety, with no courses shared between them. The graduate degree cannot be earned before the undergraduate requirements are satisfied. Admitted students who decide not to complete the MSISYE degree are permitted to count credits originally planned for the graduate program toward their undergraduate technical electives.

**Eligibility Requirements:**

- Students must be enrolled in the Mechanical Engineering undergraduate program at the University of Minnesota, Twin Cities.
- Students who are within 32 semester credits completing the requirements for the BME degree are eligible to apply.
- Students with a GPA of 3.25 or greater are preferred. For students who have transferred from another institution, at least one semester must be completed at the University of Minnesota, Twin Cities before admission to the program will be granted.
Twin Cities Campus
Industrial and Systems Engineering Minor
Industrial and Systems Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Industrial and Systems Engineering Graduate Program, University of Minnesota, 1120 Mechanical Engineering, 111 Church Street S.E., Minneapolis, MN 55455 (612-625-2009; fax: 612-624-2010)
Email: gradinfo@ie.umn.edu
Website: http://www.ie.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The industrial and systems engineering (ISyE) program offers coursework and research in industrial and systems engineering, operations research, and human factors. Special emphasis is on methodologies for design, planning, and management of service and manufacturing systems. Examples of research applications include logistics, transportation, healthcare delivery systems, revenue management, and supply chain management.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

A minimum of 6 credits are required for a master's minor and a minimum of 12 credits are required for a doctoral minor.

Program Sub-plans
Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

**Master's**
The master's minor requires 6 credits in ISyE courses at the 5xxx-level or above. The following courses may not be used: IE 8773, IE 8774, and IE 8794.

**Doctoral**
The doctoral minor requires 12 credits in ISyE courses at the 5xxx-level or above. The following courses may not be used: IE 8773, IE 8774, and IE 8794.

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
Twin Cities Campus
Industrial and Systems Engineering Ph.D.
Industrial and Systems Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Industrial and Systems Engineering Graduate Program, University of Minnesota, 1120 Mechanical Engineering, 111 Church Street S.E., Minneapolis, MN 55455 (612-625-2009; fax: 612-624-2010)
Email: gradinfo@ie.umn.edu
Website: http://www.ie.umn.edu

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 68
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The industrial and systems engineering (ISyE) program offers coursework and research in industrial and systems engineering, operations research, and human factors. Special emphasis is on methodologies for design, planning, and management of service and manufacturing systems. Examples of research applications include logistics, transportation, healthcare delivery systems, revenue management, and supply chain management.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A baccalaureate degree in engineering or a closely related field is required.

Special Application Requirements:
All application materials should be submitted electronically through the ApplyYourself application system. Students whose native language is not English are required to submit scores from one of the following English proficiency examinations: TOEFL, MELAB, or IELTS. The GRE General Test is required for students applying to the PhD program.

The application deadlines are December 15 for fall semester and October 15 for spring semester. Additional information is available at www.isye.umn.edu/apply/

Applicants must submit their test score(s) from the following:
• GRE

International applicants must submit score(s) from one of the following tests:
• TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
• IELTS
  - Total Score: 6.5

Key to test abbreviations (GRE, TOEFL, IELTS).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.
Program Requirements
32 credits are required in the major.
12 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.
Use of 4xxx courses towards program requirements is not permitted.

The PhD degree requires a minimum of 68 credits consisting of 16 required major credits, 12 course credits in a minor or a supporting program outside ISyE, 2 credits of graduate seminar, and 24 thesis credits. The remaining 14 course credits may be taken in the major or any supporting field.

Required Courses
Students may replace a required course with a qualifying replacement course if they have taken the equivalent of the required course elsewhere. A list of qualifying replacements is available on the ISyE program web page.

IE 8521 - Optimization (4.0 cr)
IE 8532 - Stochastic Processes and Queuing Systems (4.0 cr)
ME 8001 - Research Ethics and Professional Practice (0.0 cr)
Take 2 or more course(s) from the following:
• IE 5511 - Human Factors and Work Analysis (4.0 cr)
• IE 5545 - Decision Analysis (4.0 cr)
• IE 5551 - Production Planning and Inventory Control (4.0 cr)

Minor or Supporting Program
Take 12 credits in a minor or supporting program outside ISyE. The following courses may be used or consult with advisor for further options.

CSCI 5211 - Data Communications and Computer Networks (3.0 cr)
CSCI 5421 - Advanced Algorithms and Data Structures (3.0 cr)
CSCI 5521 - Introduction to Machine Learning (3.0 cr)
CSCI 8980 - Special Advanced Topics in Computer Science (1.0 - 3.0 cr)
ECON 8101 - Microeconomic Theory (2.0 cr)
ECON 8102 - Microeconomic Theory (2.0 cr)
ECON 8117 - Noncooperative Game Theory (2.0 cr)
ECON 8118 - Noncooperative Game Theory (2.0 cr)
ECON 8119 - Cooperative Game Theory (2.0 cr)
MATH 5615H - Honors: Introduction to Analysis I (4.0 cr)
MATH 5616H - Honors: Introduction to Analysis II (4.0 cr)
MATH 8601 - Real Analysis (3.0 cr)
MATH 8602 - Real Analysis (3.0 cr)
MATH 5485 - Introduction to Numerical Methods I (4.0 cr)
MATH 5486 - Introduction To Numerical Methods II (4.0 cr)
MATH 8651 - Theory of Probability Including Measure Theory (3.0 cr)
MATH 8652 - Theory of Probability Including Measure Theory (3.0 cr)
STAT 8501 - Introduction to Stochastic Processes with Applications (3.0 cr)

Seminar
Take 2 seminar credits. The following may be used or consult with advisor for further options.
IE 8773 - Graduate Seminar (1.0 cr)
IE 8774 - Graduate Seminar (1.0 cr)

Thesis Credits
Take 24 credits after passing preliminary oral exam
IE 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)

Program Sub-plans
A sub-plan is not required for this program.
Students may not complete the program with more than one sub-plan.

Industrial Engineering
Twin Cities Campus
Infrastructure Systems Management and Engineering M.S.I.S.M.E
Technological Leadership Institute
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Technological Leadership Institute, University of Minnesota, 290 McNamara Alumni Center, 200 Oak Street SE, Minneapolis MN 55455
(612-624-5474; fax: 612-624-7510)
Email: tli.info@umn.edu
Website: http://tli.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Science in Infrastructure Sys Mgmt & Eng

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Students are no longer being accepted into this program. Program requirements below are for current students only.

The master of science in infrastructure systems management and engineering (MSISME) focuses on developing management and engineering tools that address issues in local, county, and state infrastructure. It is an interdisciplinary program offered through the College of Science and Engineering's Technological Leadership Institute. The two-year, professional-format program focuses on key knowledge areas of engineering, technology, and science; management of personnel, projects, and programs; communications; governance; and synthesis. Fields of application include transportation engineering/pavement management; water resources/environmental engineering; municipal engineering; construction and maintenance; computer applications/asset management; parks, recreation and open space. The degree is offered in a hybrid online format, with in-person residencies scheduled over the course of the program.

Program Delivery
This program is available:
- primarily online (at least 80% of the instruction for the program is online with short, intensive periods of face-to-face coursework)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

Other requirements to be completed before admission:
Students are no longer being accepted into this program.

A BS degree in engineering, plus a minimum of one year of professional work experience in an infrastructure area, or a BS degree in a related science or technology field and a minimum of two years professional work experience in an infrastructure area are required.

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
Program Requirements

Plan B: Plan B requires 30 major credits and up to null credits outside the major. The final exam is oral. A capstone project is required.

Capstone Project: The capstone integrates knowledge from courses in the master's program with job experience. Students will prepare a proposal, conduct the project and report the results in written and oral form. The project will involve some aspect of the design, management, and operation of some feature of infrastructure. Students must register for the capstone course ISME 8105 (3 cr).

This program may not be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 3.25 is required for students to remain in good standing.

Required Courses
- ISME 5101 - Project Management (3.0 cr)
- ISME 5112 - Infrastructure Systems Engineering Management (2.0 cr)
- ISME 5201 - Pavement Management Maintenance and Rehabilitation (2.0 cr)
- ISME 5202 - Traffic Engineering Management (2.0 cr)
- ISME 5301 - Bridge Management Maintenance and Rehabilitation (2.0 cr)
- ISME 5302 - Critical Infrastructure Security and Protection (2.0 cr)
- ISME 5402 - Storm Water Management (2.0 cr)
- ISME 5500 - Public Interactions (1.0 cr)
- ISME 5503 - Financial Management in Public Organizations (2.0 cr)
- ISME 5504 - Construction Law and Ethics (2.0 cr)

Capstone
Take a total of 3 credits.
- ISME 8105 - Capstone Project (1.0 - 2.0 cr)

Electives
Choose at least 7 elective credits in consultation with the director of graduate studies.
Twin Cities Campus
Management of Technology M.S.M.O.T.
Technological Leadership Institute
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Management of Technology Graduate Program, Technological Leadership Institute, University of Minnesota, 290 McNamara Alumni Center, 200 Oak Street SE, Minneapolis MN 55455 (612-624-5474; fax: 612-624-7510)
Email: MOT@umn.edu
Website: http://tli.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 36
- This program does not require summer semesters for timely completion.
- Degree: Master of Science in Management of Technology

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The master of science in the management of technology (MSMOT) program is administered by the College of Sciences and Engineering's Technological Leadership Institute (TLI). The two-year, executive-format program integrates the fields of technology and management and provides working engineers and scientists with management knowledge and skills needed to assume a technical leadership role within their organizations. The program focuses on management in technology-based environments in traditional and emerging industries. The curriculum includes technical and advanced management courses, such as pivotal technologies, technology forecasting, project management, management of innovation, intellectual property management, and strategic management of technology. The core management curriculum includes areas such as finance, marketing, accounting, strategic planning and decision making, and conflict management. Students proceed through the program and advance as a cohort, taking a prescribed sequence of courses together. Case studies, class discussions, and study-group interaction stimulate the learning process. Students also participate in off-campus residencies, including an international residency; complete individual and team projects; and develop final projects as part of a capstone course. Most students receive corporate financial support.

The program is offered in a format designed for full-time working professionals. Students take courses one day per week on alternating Fridays and Saturdays and complete the degree within two years.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
A bachelor's degree in an engineering, science, or other technology-related field from an accredited program.

Other requirements to be completed before admission:
Applicants should have at least 5 years of professional experience in a technical field and have completed coursework (or show proficiency) in economics, mathematical modeling, statistics, and computer literacy.

In exceptional circumstances, promising candidates with less experience may be considered.

Special Application Requirements:
The program accepts applications on a rolling basis for fall semester of each year.

Applicants must submit three letters of recommendation, a resume, and a statement of purpose. Additional application information is available at mot.umn.edu

International applicants must submit score(s) from one of the following tests:
- TOEFL
- Internet Based - Total Score: 79
- Internet Based - Writing Score: 21
- Internet Based - Reading Score: 19
- Paper Based - Total Score: 550

IELTS
- Total Score: 6.5

MELAB
- Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

**Plan B:** Plan B requires 36 major credits and up to null credits outside the major. The final exam is oral. A capstone project is required.

**Capstone Project:** The capstone project consists of an independent, original investigation requiring between 110 and 130 hours of effort. Students use concepts and methods learned in the MOT program to research and develop an industry-based product, project, process, or venture. The capstone project enables students to directly apply their MOT education at work.

This program may not be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 3.25 is required for students to remain in good standing.

Students attend the program as a cohort and complete their studies in four semesters.

**Required Courses (33.5 Credits)**

Take the following courses for a total of 33.5 credits:

- MOT 8111 - Marketing Management for Technology-based Organizations (2.0 cr)
- MOT 8112 - Accounting for Decision Making (1.5 cr)
- MOT 8113 - Operations Management for Competitive Advantage (1.5 cr)
- MOT 8114 - Strategic Technology Analysis (1.5 cr)
- MOT 8121 - Managing Organizations in a Technological Environment (2.0 cr)
- MOT 8122 - Financial Management for Technology-based Organizations (2.0 cr)
- MOT 8133 - Managerial Communication for Technological Leaders: Persuasive Writing and Speaking (2.0 cr)
- MOT 8212 - Developing New Technology Products (2.0 cr)
- MOT 8213 - Macroenvironment of Technology (1.5 cr)
- MOT 8214 - Technology Foresight and Forecasting (2.0 cr)
- MOT 8221 - Project and Knowledge Management (1.5 cr)
- MOT 8224 - Pivotal Technologies (1.0 cr)
- MOT 8232 - Managing Technological Innovation (2.0 cr)
- MOT 8233 - Strategic Management of Technology (2.0 cr)
- MOT 8501 - Leading Individual & Team Performance (1.5 cr)
- MOT 8502 - Innovation Leadership and Organizational Effectiveness (1.0 cr)
- MOT 8900 - Conflict Management (0.5 cr)
- MOT 8920 - Science and Technology Policy (1.5 cr)
- MOT 8940 - Managing Intellectual Property (1.0 cr)
- MOT 8950 - International Management of Technology Project (2.0 cr)

Take MOT 8960 twice for a total of two credits.

- MOT 8960 - Seminars in Management of Technology (MOT) and Innovation (1.0 cr)

**Capstone Project (2.5 Credits)**

Take MOT 8234 for a total of 2.5 credits to complete the 36-credit requirement.

- MOT 8234 - Capstone Project (0.5 - 2.5 cr)
Twin Cities Campus
Management of Technology Minor
Technological Leadership Institute
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Technological Leadership Institute, College of Science and Engineering, University of Minnesota, Suite 290 McNamara Alumni Center, 200 Oak Street SE, Minneapolis MN 55455
Phone: 612-624-5747
Fax: 612-624-7510
Email: mot@umn.edu
Website: http://www.tli.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The management of technology minor program is administered by the Technological Leadership Institute (TLI) in the College of Science and Engineering. The program integrates the fields of technology and management, allowing students in science and engineering majors to develop understanding and expertise in business principles. The curriculum includes basic business knowledge, with an emphasis on technology-intensive organizations. Topics include strategy, finance, marketing, intellectual property, innovation, and technology planning. Each class will include exercises that inform students on those business topics, and give them an opportunity to practice the fundamental skills of communications, teamwork and project management.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
A bachelor's degree in an engineering, science, or other technology-related field from an accredited program.

Special Application Requirements:
Applicants for the minor must be enrolled in a graduate-level degree program at the University of Minnesota and have director of graduate studies approval.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

The MOT minor requires two core courses for a total of 4 credits. The remaining credits can be taken from the list of approved electives.

MOT minor courses cannot be counted towards the master of science in management of technology degree requirements.

Core Courses
- MOT 5001 - Technological Business Fundamentals (2.0 cr)
- MOT 5002 - Creating Technological Innovation (2.0 cr)
Program Sub-plans

Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

Masters

Electives

Other courses may be chosen in consultation with the director of graduate studies.

Take 2 or more credits from the following:

- MOT 5003 - Technological Business Planning Workshop (1.0 cr)
- ENTR 6020 - Business Formation (4.0 cr)
- ENTR 6036 - Managing the Growing Business (2.0 cr)
- HSCI 5401 - Ethics in Science and Technology (3.0 cr)
- HSCI 5421 - Engineering Ethics (3.0 cr)
- IDSC 6040 - Information Technology Management (2.0 cr)
- IDSC 6423 - Enterprise Systems (2.0 cr)
- IE 5111 - Systems Engineering I (2.0 cr)
- IE 5441 - Financial Decision Making (4.0 cr)
- IE 5541 - Project Management (4.0 cr)
- MBA 6110 - Leading Others (2.0 cr)
- MBA 6300 - Strategic Management (3.0 cr)
- ME 8221 - New Product Design and Business Development I (4.0 cr)
- ME 8222 - New Product Design and Business Development II (4.0 cr)
- MGMT 6004 - Negotiation Strategies (2.0 cr)
- MGMT 6040 - International Strategy and Organization (2.0 cr)
- MGMT 6084 - Management of Groups (2.0 cr)
- MGMT 6305 - The International Environment of Business (4.0 cr)
- MILI 5589 - Medical Technology Evaluation and Market Research (2.0 cr)
- OLPD 5607 - Organization Development (3.0 cr)
- PA 5711 - Science, Technology & Environmental Policy (3.0 cr)
- PA 5741 - Risk, Resilience and Decision Making (1.5 cr)

Doctoral

Electives

Other courses may be chosen in consultation with the director of graduate studies.

Take 8 or more credits from the following:

- MOT 5003 - Technological Business Planning Workshop (1.0 cr)
- ENTR 6020 - Business Formation (4.0 cr)
- ENTR 6036 - Managing the Growing Business (2.0 cr)
- HSCI 5401 - Ethics in Science and Technology (3.0 cr)
- HSCI 5421 - Engineering Ethics (3.0 cr)
- IDSC 6040 - Information Technology Management (2.0 cr)
- IDSC 6423 - Enterprise Systems (2.0 cr)
- IE 5111 - Systems Engineering I (2.0 cr)
- IE 5441 - Financial Decision Making (4.0 cr)
- IE 5541 - Project Management (4.0 cr)
- MBA 6110 - Leading Others (2.0 cr)
- MBA 6300 - Strategic Management (3.0 cr)
- ME 8221 - New Product Design and Business Development I (4.0 cr)
- ME 8222 - New Product Design and Business Development II (4.0 cr)
- MGMT 6004 - Negotiation Strategies (2.0 cr)
- MGMT 6040 - International Strategy and Organization (2.0 cr)
- MGMT 6084 - Management of Groups (2.0 cr)
- MGMT 6305 - The International Environment of Business (4.0 cr)
- MILI 5589 - Medical Technology Evaluation and Market Research (2.0 cr)
- OLPD 5607 - Organization Development (3.0 cr)
- PA 5711 - Science, Technology & Environmental Policy (3.0 cr)
- PA 5741 - Risk, Resilience and Decision Making (1.5 cr)
Twin Cities Campus
Materials Science and Engineering M.Mat.S.E.
Chemical Engineering & Materials Science
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Chemical Engineering and Materials Science, University of Minnesota, 151 Amundson Hall, 421 Washington Avenue SE, Minneapolis, MN 55455 (612-625-0382; fax: 612-626-7246)
Email: cemsgrad@umn.edu
Website: http://www.cems.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Materials Science And Engineering

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Graduate courses offered by the Chemical Engineering and Materials Science (CEMS) Department cover core areas of materials science and engineering (structure and symmetry of materials; thermodynamics and kinetics; electronic, optical, and magnetic properties of materials; and mechanical properties of materials). In addition, several specialized topics are offered, including rheology, coating process fundamentals, process control, finite element methods of computer-aided analysis, ceramics, polymers, materials design and performance, materials processing, corrosion, contact and fracture properties of materials, electron microscopy, thin films and interfaces, composites, electrochemical engineering, solid state reaction kinetics, electronic structure of materials, organic semiconductors, electronic ceramics, dislocations and interfaces, epitaxial thin film growth, and the science of porous media.

The master of materials science and engineering (M.Mat.S.E.), also known as the professional master's, is designed for working professionals who are interested in obtaining a master's degree part time. This degree requires a design project. Part-time students may also choose the M.S.Mat.S.E. Plan C, which is coursework only.

The CEMS department focuses on the PhD and does not generally admit students directly to the M.S.Mat.S.E. Plan A degree, which is a thesis based master's and is intended for current graduate students who choose not to seek a PhD.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
A bachelor's degree in materials science or other related field.

Other requirements to be completed before admission:
The professional master's in engineering degree is designed for employees of local industries who wish to pursue their studies part-time. No financial support is available. Applicants should contact the program before applying for admission.

Special Application Requirements:
Applicants must submit scores from the General Test of the GRE; three letters of recommendation from persons familiar with their scholarship and research potential; a complete set of official transcripts; and a clearly written statement of career interests, goals, and objectives. International students are required to provide TOEFL results.

Applications are accepted for fall semester only. December 15 is the application deadline; late applications are considered if space is available. More information is available at http://www.cems.umn.edu/graduate/admissions

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
Program Requirements

Plan A: Plan A requires 12 to 14 major credits, 6 to 8 credits outside the major, and 10 thesis credits. The final exam is oral.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 2.80 is required for students to remain in good standing.

The M.Mat.S.E. requires 20 course credits and 10 thesis credits. The course credits must include 12 credits in MATS core courses, and a minimum of 6 credits outside the major. The remaining credits may be taken in the major or in any supporting field.

In addition to the coursework, M.Mat.S.E. students are required to complete a design project. The work-related M.Mat.S.E. design project consists of an in-depth study of an engineering design. It need not represent a publishable research project. While the amount of work should be the same as for a master's thesis, the project can contain elements that the thesis would not, such as economic considerations, design consultation, and social relevance. The written design report must be approved by a three-person faculty committee. The final exam consists of the written design report and an oral presentation to the faculty committee.

Core Courses

- MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
- MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
- MATS 8003 - Electronic Properties (3.0 cr)
- MATS 8004 - Mechanical Properties (3.0 cr)

Thesis Credits

- 10 thesis credits are required for the design project.
- MAT 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Electives

The remaining credits may be chosen from the following list. Consult with advisor for further options.

- AEM 4201 - Fluid Mechanics (4.0 cr)
- AEM 4511 - Mechanics of Composite Materials (3.0 cr)
- AEM 5501 - Continuum Mechanics (3.0 cr)
- AEM 5503 - Theory of Elasticity (3.0 cr)
- AEM 8251 - Finite-Volume Methods in Computational Fluid Dynamics (3.0 cr)
- AEM 8531 - Fracture Mechanics (3.0 cr)
- BMEN 5001 - Advanced Biomaterials (3.0 cr)
- BMEN 5041 - Tissue Engineering (3.0 cr)
- BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
- BMEN 5201 - Advanced Biomechanics (3.0 cr)
- BMEN 5501 - Biology for Biomedical Engineers (3.0 cr)
- BMEN 8511 - Systems and Synthetic Biology (3.0 cr)
- CEGE 8022 - Numerical Methods for Free and Moving Boundary Problems (3.0 cr)
- CEGE 8401 - Fundamentals of Finite Element Method (3.0 cr)
- CEGE 8402 - Nonlinear Finite Element Analysis (3.0 cr)
- CEGE 8501 - Environmental Fluid Mechanics I (4.0 cr)
- CEGE 8502 - Environmental Fluid Mechanics II (4.0 cr)
- CEGE 8504 - Theory of Unit Operations (4.0 cr)
- CEGE 8505 - Biological Processes (3.0 cr)
- CHEM 5210 - Materials Characterization (4.0 cr)
- CHEM 5755 - X-Ray Crystallography (4.0 cr)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 8011</td>
<td>Mechanisms of Chemical Reactions</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8152</td>
<td>Analytical Spectroscopy</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8201</td>
<td>Materials Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8221</td>
<td>Synthetic Polymer Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8321</td>
<td>Organic Synthesis</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8322</td>
<td>Advanced Organic Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8361</td>
<td>Interpretation of Organic Spectra</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8551</td>
<td>Quantum Mechanics I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8552</td>
<td>Quantum Mechanics II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8561</td>
<td>Thermodynamics, Statistical Mechanics, and Reaction Dynamics I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8562</td>
<td>Thermodynamics, Statistical Mechanics, and Reaction Dynamics II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 5753</td>
<td>Advanced Biomedical Transport Processes</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEM 5771</td>
<td>Colloids and Dispersions</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEM 8101</td>
<td>Fluid Mechanics I: Change, Deformation, Equations of Flow</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEM 8102</td>
<td>Principles and Applications of Rheology</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>CHEM 8104</td>
<td>Coating Process Fundamentals</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>CHEM 8201</td>
<td>Applied Math</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEM 8301</td>
<td>Physical Rate Processes I: Transport</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEM 8402</td>
<td>Statistical Thermodynamics and Kinetics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEM 8501</td>
<td>Chemical Rate Processes: Analysis of Chemical Reactors</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEM 8754</td>
<td>Systems Analysis of Biological Processes</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5163</td>
<td>Semiconductor Properties and Devices I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5164</td>
<td>Semiconductor Properties and Devices II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5171</td>
<td>Microelectronic Fabrication</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 5173</td>
<td>Basic Microelectronics Laboratory</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>EE 5181</td>
<td>Micro and Nanotechnology by Self Assembly</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5621</td>
<td>Physical Optics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5622</td>
<td>Physical Optics Laboratory</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>EE 5624</td>
<td>Optical Electronics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 5653</td>
<td>Physical Principles of Magnetic Materials</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5655</td>
<td>Magnetic Recording</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>GCD 5036</td>
<td>Molecular Cell Biology</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 4428</td>
<td>Mathematical Modeling</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4512</td>
<td>Differential Equations with Applications</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 5485</td>
<td>Introduction to Numerical Methods I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5486</td>
<td>Introduction to Numerical Methods II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5525</td>
<td>Introduction to Ordinary Differential Equations</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5535</td>
<td>Dynamical Systems and Chaos</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5587</td>
<td>Elementary Partial Differential Equations I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5588</td>
<td>Elementary Partial Differential Equations II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5651</td>
<td>Basic Theory of Probability and Statistics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5652</td>
<td>Introduction to Stochastic Processes</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 8441</td>
<td>Numerical Analysis and Scientific Computing</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8442</td>
<td>Numerical Analysis and Scientific Computing</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 4212</td>
<td>Ceramics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 4214</td>
<td>Polymers</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 5353</td>
<td>Electron Microprobe Theory and Practice</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 5517</td>
<td>Electron Microscopy</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 5531</td>
<td>Electrochemical Engineering</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 8201</td>
<td>Applied Math</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 8211</td>
<td>Physical Chemistry of Polymers</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATS 8221</td>
<td>Synthetic Polymer Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATS 8301</td>
<td>Physical Rate Processes I: Transport</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>ME 5228</td>
<td>Introduction to Finite Element Modeling, Analysis, and Design</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5247</td>
<td>Stress Analysis, Sensing, and Transducers</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5446</td>
<td>Introduction to Combustion</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 8390</td>
<td>Advanced Topics in the Thermal Sciences</td>
<td>1.0 - 3.0 cr</td>
</tr>
<tr>
<td>NSCI 5300</td>
<td>Biological Microscopy &amp; Digital Imaging</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 5001</td>
<td>Quantum Mechanics I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 5002</td>
<td>Quantum Mechanics II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 5081</td>
<td>Introduction to Biopolymer Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 5201</td>
<td>Thermal and Statistical Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 5701</td>
<td>Solid-State Physics for Engineers and Scientists</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 8001</td>
<td>Advanced Quantum Mechanics</td>
<td>3.0 cr</td>
</tr>
</tbody>
</table>

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
PHYS 8702 - Statistical Mechanics and Transport Theory (3.0 cr)
PHYS 8711 - Solid-State Physics I (3.0 cr)
PHYS 8712 - Solid-State Physics II (3.0 cr)
STAT 5021 - Statistical Analysis (4.0 cr)

Special Topics Electives
The following electives are topics courses. Only the approved topic titles below may be used.
AEM 8511 Advanced Topics in Continuum Mechanics - Problems in Materials Science
CEGE 5180 Special Topics - Membrane Science and Technology
EE 5940 Special Topics - Thin Films and Nanostructures: Materials and Devices
EE 8950 Advanced Topics - Materials & Design for Future Nonvolatile Memory
GCD 8920 Special Topics - Quantitative Fluorescence Microscopy
Math 8450 Topics in Numerical Analysis - Applications of Continuum Mechanics in Biology
Twin Cities Campus
Materials Science and Engineering M.S.Mat.S.E.
Chemical Engineering & Materials Science
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Chemical Engineering and Materials Science, University of Minnesota, 151 Amundson Hall, 421 Washington Avenue SE, Minneapolis, MN 55455 (612-625-0382; fax: 612-626-7246)
Email: cemsgrad@umn.edu
Website: http://www.cems.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program requires summer semesters for timely completion.
- Degree: Master of Science Materials Science And Engr

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The CEMS Department offers two types of master's degrees: the M.S.Mat.S.E. (Plan A or C) and the M.Mat.S.E. degree, also known as the professional master's. The M.S.Mat.S.E. Plan A degree is a thesis-based master's and is generally reserved only for current graduate students who choose not to seek a PhD. Working professionals who are interested in obtaining a master's degree part time should follow the requirements for the M.Mat.S.E. degree, which requires a design project, or the M.S.Mat.S.E. Plan C, which is coursework only.

Graduate courses offered by CEMS cover core areas of materials science and engineering (structure and symmetry of materials; thermodynamics and kinetics; electronic, optical, and magnetic properties of materials; and mechanical properties of materials). In addition, several specialized topics are offered, including rheology, coating process fundamentals, process control, finite element methods of computer-aided analysis, ceramics, polymers, materials design and performance, materials processing, corrosion, contact and fracture properties of materials, electron microscopy, thin films and interfaces, composites, electrochemical engineering, solid state reaction kinetics, electronic structure of materials, organic semiconductors, electronic ceramics, dislocations and interfaces, epitaxial thin film growth, and the science of porous media.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
A bachelor's degree in materials science or other related field.

Other requirements to be completed before admission:
With the exception of the professional master's degree (the M.Mat.S.E.) and the M.S.Mat.S.E. Plan C, the CEMS department focuses on the PhD and does not generally admit students directly to the M.S.Mat.S.E. Plan A degree.

Special Application Requirements:
Applicants must submit scores from the General Test of the GRE; three letters of recommendation from persons familiar with their scholarship and research potential; a complete set of official transcripts; and a clearly written statement of career interests, goals, and objectives. International students are required to provide TOEFL results.

Applications are accepted for fall semester only. December 15 is the application deadline; late applications are considered if space is available. More information is available at http://www.cems.umn.edu/graduate/admissions

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
Program Requirements

**Plan A:** Plan A requires 12 to 14 major credits, 6 to 8 credits outside the major, and 10 thesis credits. The final exam is written and oral.

**Plan C:** Plan C requires 12 to 18 major credits and 12 to 18 credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 2.80 is required for students to remain in good standing.

**Core Courses**

- **MATS 8001** - Structure and Symmetry of Materials (3.0 cr)
- **MATS 8002** - Thermodynamics and Kinetics (3.0 cr)
- **MATS 8003** - Electronic Properties (3.0 cr)
- **MATS 8004** - Mechanical Properties (3.0 cr)

**Plan A**

The Plan A requires 12 credits in core MATS coursework, 6 credits outside the major, and 10 thesis credits. The remaining course credits may be taken in the major or in any supporting field.

**MATS 8777** - Thesis Credits: Master's (1.0 - 18.0 cr)

**Plan C**

The Plan C requires 12 credits in core MATS coursework, and 12 credits outside the major. The remaining course credits may be taken in the major or in any supporting field.

**Electives**

The remaining credits may be chosen from the following list or consult with advisor for further options.

- **AEM 4201** - Fluid Mechanics (4.0 cr)
- **AEM 4511** - Mechanics of Composite Materials (3.0 cr)
- **AEM 5501** - Continuum Mechanics (3.0 cr)
- **AEM 5503** - Theory of Elasticity (3.0 cr)
- **AEM 8251** - Finite-Volume Methods in Computational Fluid Dynamics (3.0 cr)
- **AEM 8531** - Fracture Mechanics (3.0 cr)
- **BMEN 5001** - Advanced Biomaterials (3.0 cr)
- **BMEN 5041** - Tissue Engineering (3.0 cr)
- **BMEN 5201** - Advanced Biomechanics (3.0 cr)
- **BMEN 5501** - Biology for Biomedical Engineers (3.0 cr)
- **BMEN 8511** - Systems and Synthetic Biology (3.0 cr)
- **CEGE 8022** - Numerical Methods for Free and Moving Boundary Problems (3.0 cr)
- **CEGE 8401** - Fundamentals of Finite Element Method (3.0 cr)
- **CEGE 8402** - Nonlinear Finite Element Analysis (3.0 cr)
- **CEGE 8501** - Environmental Fluid Mechanics I (4.0 cr)
- **CEGE 8502** - Environmental Fluid Mechanics II (4.0 cr)
- **CEGE 8504** - Theory of Unit Operations (4.0 cr)
- **CEGE 8505** - Biological Processes (3.0 cr)
- **CHEM 5210** - Materials Characterization (4.0 cr)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 5755</td>
<td>X-Ray Crystallography</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8011</td>
<td>Mechanisms of Chemical Reactions</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8152</td>
<td>Analytical Spectroscopy</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8201</td>
<td>Materials Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8221</td>
<td>Synthetic Polymer Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8321</td>
<td>Organic Synthesis</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8322</td>
<td>Advanced Organic Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8361</td>
<td>Interpretation of Organic Spectra</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8551</td>
<td>Quantum Mechanics I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8552</td>
<td>Quantum Mechanics II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8561</td>
<td>Thermodynamics, Statistical Mechanics, and Reaction Dynamics I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEM 8562</td>
<td>Thermodynamics, Statistical Mechanics, and Reaction Dynamics II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>CHEN 5753</td>
<td>Advanced Biomedical Transport Processes</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 5771</td>
<td>Colloids and Dispersions</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8101</td>
<td>Fluid Mechanics I: Change, Deformation, Equations of Flow</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8102</td>
<td>Principles and Applications of Rheology</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>CHEN 8104</td>
<td>Coating Process Fundamentals</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>CHEN 8201</td>
<td>Applied Math</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8301</td>
<td>Physical Rate Processes I: Transport</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8402</td>
<td>Statistical Thermodynamics and Kinetics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8501</td>
<td>Chemical Rate Processes: Analysis of Chemical Reactors</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CHEN 8754</td>
<td>Systems Analysis of Biological Processes</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5163</td>
<td>Semiconductor Properties and Devices I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5164</td>
<td>Semiconductor Properties and Devices II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5171</td>
<td>Microelectronic Fabrication</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 5173</td>
<td>Basic Microelectronics Laboratory</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>EE 5181</td>
<td>Micro and Nanotechnology by Self Assembly</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5621</td>
<td>Physical Optics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5622</td>
<td>Physical Optics Laboratory</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>EE 5624</td>
<td>Optical Electronics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 5653</td>
<td>Physical Principles of Magnetic Materials</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5655</td>
<td>Magnetic Recording</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5657</td>
<td>Physical Principles of Thin Film Technology</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ESCI 5353</td>
<td>Electron Microprobe Theory and Practice</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>GCD 5036</td>
<td>Molecular Cell Biology</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 4428</td>
<td>Mathematical Modeling</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 4512</td>
<td>Differential Equations with Applications</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 5485</td>
<td>Introduction to Numerical Methods I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5486</td>
<td>Introduction To Numerical Methods II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5525</td>
<td>Introduction to Ordinary Differential Equations</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5535</td>
<td>Dynamical Systems and Chaos</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5587</td>
<td>Elementary Partial Differential Equations I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5588</td>
<td>Elementary Partial Differential Equations II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5651</td>
<td>Basic Theory of Probability and Statistics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 5652</td>
<td>Introduction to Stochastic Processes</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATH 8441</td>
<td>Numerical Analysis and Scientific Computing</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATH 8442</td>
<td>Numerical Analysis and Scientific Computing</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 4212</td>
<td>Ceramics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 4214</td>
<td>Polymers</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 5353</td>
<td>Electron Microprobe Theory and Practice</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 5517</td>
<td>Electron Microscopy</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 5531</td>
<td>Electrochemical Engineering</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 8201</td>
<td>Applied Math</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>MATS 8211</td>
<td>Physical Chemistry of Polymers</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATS 8221</td>
<td>Synthetic Polymer Chemistry</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>MATS 8301</td>
<td>Physical Rate Processes I: Transport</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>ME 5226</td>
<td>Introduction to Finite Element Modeling, Analysis, and Design</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5247</td>
<td>Stress Analysis, Sensing, and Transducers</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 5446</td>
<td>Introduction to Combustion</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>ME 8390</td>
<td>Advanced Topics in the Thermal Sciences</td>
<td>1.0 - 3.0 cr</td>
</tr>
<tr>
<td>NSCI 5300</td>
<td>Biological Microscopy &amp; Digital Imaging</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 5001</td>
<td>Quantum Mechanics I</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 5002</td>
<td>Quantum Mechanics II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 5081</td>
<td>Introduction to Biopolymer Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 5201</td>
<td>Thermal and Statistical Physics</td>
<td>3.0 cr</td>
</tr>
</tbody>
</table>
PHYS 5701 - Solid-State Physics for Engineers and Scientists (4.0 cr)
PHYS 8001 - Advanced Quantum Mechanics (3.0 cr)
PHYS 8702 - Statistical Mechanics and Transport Theory (3.0 cr)
PHYS 8711 - Solid-State Physics I (3.0 cr)
PHYS 8712 - Solid-State Physics II (3.0 cr)
STAT 5021 - Statistical Analysis (4.0 cr)

Special Topics Electives
The following electives are topics courses. Only the approved topic titles below may be used.
AEM 8511 Advanced Topics in Continuum Mechanics - Problems in Materials Science
CEGE 5180 Special Topics - Membrane Science and Technology
EE 5940 Special Topics - Thin Films and Nanostructures: Materials and Devices
EE 8950 Advanced Topics - Materials & Design for Future Nonvolatile Memory
GCD 8920 Special Topics - Quantitative Fluorescence Microscopy
Math 8450 Topics in Numerical Analysis - Applications of Continuum Mechanics in Biology
Twin Cities Campus
Materials Science and Engineering Minor
Chemical Engineering & Materials Science
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Chemical Engineering and Materials Science, University of Minnesota, 151 Amundson Hall, 421 Washington Avenue SE, Minneapolis, MN 55455 (612-625-0382; fax: 612-626-7246)
Email: cemsgrad@umn.edu
Website: http://www.cems.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Graduate courses offered by the Chemical Engineering and Materials Science (CEMS) Department cover core areas of materials science and engineering (structure and symmetry of materials; thermodynamics and kinetics; electronic, optical, and magnetic properties of materials; and mechanical properties of materials). In addition, several specialized topics are offered, including rheology, coating process fundamentals, process control, finite element methods of computer-aided analysis, ceramics, polymers, materials design and performance, materials processing, corrosion, contact and fracture properties of materials, electron microscopy, thin films and interfaces, composites, electrochemical engineering, solid state reaction kinetics, electronic structure of materials, organic semiconductors, electronic ceramics, dislocations and interfaces, epitaxial thin film growth, and the science of porous media.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

The minor must be approved by the director of graduate studies in materials science and engineering.

Program Sub-plans
Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

Masters
Core Courses
Take 2 or more course(s) totaling 6 or more credit(s) from the following:
- MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
- MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
- MATS 8003 - Electronic Properties (3.0 cr)
- MATS 8004 - Mechanical Properties (3.0 cr)
Doctoral

Core Courses
Take all 4 core courses for a total of 12 credits.

MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
MATS 8003 - Electronic Properties (3.0 cr)
MATS 8004 - Mechanical Properties (3.0 cr)
Twin Cities Campus
Materials Science and Engineering Ph.D.
Chemical Engineering & Materials Science
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Department of Chemical Engineering and Materials Science, University of Minnesota, 151 Amundson Hall, 421 Washington Avenue SE, Minneapolis, MN 55455 (612-625-0382; fax: 612-626-7246)
Email: cemsgrad@umn.edu
Website: http://www.cems.umn.edu

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 57
- This program requires summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Graduate courses offered by the Chemical Engineering and Materials Science (CEMS) Department cover core areas of materials science and engineering (structure and symmetry of materials; thermodynamics and kinetics; electronic, optical, and magnetic properties of materials; and mechanical properties of materials). In addition, several specialized topics are offered, including rheology, coating process fundamentals, process control, finite element methods of computer-aided analysis, ceramics, polymers, materials design and performance, materials processing, corrosion, contact and fracture properties of materials, electron microscopy, thin films and interfaces, composites, electrochemical engineering, solid state reaction kinetics, electronic structure of materials, organic semiconductors, electronic ceramics, dislocations and interfaces, epitaxial thin film growth, and the science of porous media.

Program Delivery
This program is available:
  - via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
A bachelor’s degree in materials science or other related field.

Other requirements to be completed before admission:
Applicants must submit scores from the general test of the GRE, three letters of recommendation from persons familiar with their scholarship and research potential, a complete set of official transcripts, and a clearly written statement of career interests, goals, and objectives. International students are required to provide TOEFL results.

Special Application Requirements:
Applications are accepted for fall semester only. Submission of all application materials by December 15 is strongly encouraged to ensure priority consideration for fellowships and assistantships; late applications are considered if space is available. More information is available at http://www.cems.umn.edu/graduate/admissions

Applicants must submit their test score(s) from the following:
  - GRE

International applicants must submit score(s) from one of the following tests:
  - TOEFL
    - Internet Based - Total Score: 79
    - Internet Based - Writing Score: 21
    - Internet Based - Reading Score: 19
    - Paper Based - Total Score: 560
  - IELTS
    - Total Score: 6.5
  - MELAB
    - Final score: 80
Key to test abbreviations (GRE, TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
21 credits are required in the major.
12 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

The PhD requires 33 course credits and 24 thesis credits. The course credits must include 12 credits in four core MATS courses, and a minimum of 12 credits outside the major. The remaining 9 credits may be taken in the major or in any supporting field.

Students must attend, but not enroll in, the departmental seminar for six semesters. Informal attendance will be done within the department.

Core Courses
- MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
- MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
- MATS 8003 - Electronic Properties (3.0 cr)
- MATS 8004 - Mechanical Properties (3.0 cr)

Thesis Credits
Take 24 credits after passing preliminary oral exam
- MATS 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)

Electives
The remaining credits may be chosen from the following list or consult with advisor for further options.
- AEM 4201 - Fluid Mechanics (4.0 cr)
- AEM 4511 - Mechanics of Composite Materials (3.0 cr)
- AEM 5501 - Continuum Mechanics (3.0 cr)
- AEM 5503 - Theory of Elasticity (3.0 cr)
- AEM 8251 - Finite-Volume Methods in Computational Fluid Dynamics (3.0 cr)
- AEM 8531 - Fracture Mechanics (3.0 cr)
- BMEN 5001 - Advanced Biomaterials (3.0 cr)
- BMEN 5041 - Tissue Engineering (3.0 cr)
- BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
- BMEN 5201 - Advanced Biomechanics (3.0 cr)
- BMEN 5501 - Biology for Biomedical Engineers (3.0 cr)
- BMEN 8511 - Systems and Synthetic Biology (3.0 cr)
- CEGE 8022 - Numerical Methods for Free and Moving Boundary Problems (3.0 cr)
- CEGE 8401 - Fundamentals of Finite Element Method (3.0 cr)
- CEGE 8402 - Nonlinear Finite Element Analysis (3.0 cr)
- CEGE 8501 - Environmental Fluid Mechanics I (4.0 cr)
- CEGE 8502 - Environmental Fluid Mechanics II (4.0 cr)
- CEGE 8504 - Theory of Unit Operations (4.0 cr)
- CEGE 8505 - Biological Processes (3.0 cr)
- CHEM 5210 - Materials Characterization (4.0 cr)
- CHEM 5755 - X-Ray Crystallography (4.0 cr)
- CHEM 8011 - Mechanisms of Chemical Reactions (4.0 cr)
- CHEM 8152 - Analytical Spectroscopy (4.0 cr)
- CHEM 8201 - Materials Chemistry (4.0 cr)
- CHEM 8221 - Synthetic Polymer Chemistry (4.0 cr)
- CHEM 8321 - Organic Synthesis (4.0 cr)
- CHEM 8322 - Advanced Organic Chemistry (4.0 cr)
- CHEM 8361 - Interpretation of Organic Spectra (4.0 cr)
- CHEM 8551 - Quantum Mechanics I (4.0 cr)
CHEM 8552 - Quantum Mechanics II (4.0 cr)
CHEM 8561 - Thermodynamics, Statistical Mechanics, and Reaction Dynamics I (4.0 cr)
CHEM 8562 - Thermodynamics, Statistical Mechanics, and Reaction Dynamics II (4.0 cr)
CHEN 5753 - Advanced Biomedical Transport Processes (3.0 cr)
CHEN 5771 - Colloids and Dispersions (3.0 cr)
CHEN 8101 - Fluid Mechanics I: Change, Deformation, Equations of Flow (3.0 cr)
CHEN 8102 - Principles and Applications of Rheology (2.0 cr)
CHEN 8104 - Coating Process Fundamentals (2.0 cr)
CHEN 8201 - Applied Math (3.0 cr)
CHEN 8301 - Physical Rate Processes I: Transport (3.0 cr)
CHEN 8402 - Statistical Thermodynamics and Kinetics (3.0 cr)
CHEN 8501 - Chemical Rate Processes: Analysis of Chemical Reactors (3.0 cr)
CHEN 8754 - Systems Analysis of Biological Processes (3.0 cr)
EE 5163 - Semiconductor Properties and Devices I (3.0 cr)
EE 5164 - Semiconductor Properties and Devices II (3.0 cr)
EE 5171 - Microelectronic Fabrication (4.0 cr)
EE 5173 - Basic Microelectronics Laboratory (1.0 cr)
EE 5181 - Micro and Nanotechnology by Self Assembly (3.0 cr)
EE 5621 - Physical Optics (3.0 cr)
EE 5622 - Physical Optics Laboratory (1.0 cr)
EE 5624 - Optical Electronics (4.0 cr)
EE 5657 - Physical Principles of Thin Film Technology (4.0 cr)
ESCI 5353 - Electron Microprobe Theory and Practice (3.0 cr)
GCD 5036 - Molecular Cell Biology (3.0 cr)
MATH 4428 - Mathematical Modeling (4.0 cr)
MATH 4512 - Differential Equations with Applications (3.0 cr)
MATH 5485 - Introduction to Numerical Methods I (4.0 cr)
MATH 5486 - Introduction To Numerical Methods II (4.0 cr)
MATH 5525 - Introduction to Ordinary Differential Equations (4.0 cr)
MATH 5535 - Dynamical Systems and Chaos (4.0 cr)
MATH 5557 - Elementary Partial Differential Equations I (4.0 cr)
MATH 5558 - Elementary Partial Differential Equations II (4.0 cr)
MATH 5651 - Basic Theory of Probability and Statistics (4.0 cr)
MATH 5652 - Introduction to Stochastic Processes (4.0 cr)
MATH 5841 - Numerical Analysis and Scientific Computing (3.0 cr)
MATS 4212 - Ceramics (3.0 cr)
MATS 4214 - Polymers (3.0 cr)
MATS 5353 - Electron Microprobe Theory and Practice (3.0 cr)
MATS 5517 - Electron Microscopy (3.0 cr)
MATS 5531 - Electrochemical Engineering (3.0 cr)
MATS 8001 - Structure and Symmetry of Materials (3.0 cr)
MATS 8002 - Thermodynamics and Kinetics (3.0 cr)
MATS 8003 - Electronic Properties (3.0 cr)
MATS 8004 - Mechanical Properties (3.0 cr)
MATS 8201 - Applied Math (3.0 cr)
MATS 8211 - Physical Chemistry of Polymers (4.0 cr)
MATS 8221 - Synthetic Polymer Chemistry (4.0 cr)
MATS 8301 - Physical Rate Processes I: Transport (3.0 cr)
ME 5228 - Introduction to Finite Element Modeling, Analysis, and Design (4.0 cr)
ME 5247 - Stress Analysis, Sensing, and Transducers (4.0 cr)
ME 5446 - Introduction to Combustion (4.0 cr)
ME 8390 - Advanced Topics in the Thermal Sciences (1.0 - 3.0 cr)
NSCI 5300 - Biological Microscopy & Digital Imaging (3.0 cr)
PHYS 5001 - Quantum Mechanics I (4.0 cr)
PHYS 5002 - Quantum Mechanics II (4.0 cr)
PHYS 5081 - Introduction to Biopolymer Physics (3.0 cr)
PHYS 5201 - Thermal and Statistical Physics (3.0 cr)
PHYS 5701 - Solid-State Physics for Engineers and Scientists (4.0 cr)
PHYS 8001 - Advanced Quantum Mechanics (3.0 cr)
PHYS 8702 - Statistical Mechanics and Transport Theory (3.0 cr)
PHYS 8711 - Solid-State Physics I (3.0 cr)
PHYS 8712 - Solid-State Physics II (3.0 cr)
STAT 5021 - Statistical Analysis (4.0 cr)

Special Topics Electives
The following electives are topics courses. Only the approved topic titles below may be used.
AEM 8511 Advanced Topics in Continuum Mechanics - Problems in Materials Science
CEGE 5180 Special Topics - Membrane Science and Technology
EE 5940 Special Topics - Thin Films and Nanostructures: Materials and Devices
EE 8950 Advanced Topics - Materials & Design for Future Nonvolatile Memory
GCD 8920 Special Topics - Quantitative Fluorescence Microscopy
Math 8450 Topics in Numerical Analysis - Applications of Continuum Mechanics in Biology
Twin Cities Campus
Mathematics M.S.
School of Mathematics
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
School of Mathematics, University of Minnesota, 127 Vincent Hall, 206 Church Street SE, Minneapolis, MN 55455 (612-624-6391; fax: 612-624-6702)
Email: gradprog@math.umn.edu
Website: http://www.math.umn.edu/grad/

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The School of Mathematics offers a master of science (MS) in mathematics. Students may also earn the MS degree with emphasis in applied and industrial mathematics or with emphasis in mathematics education.

Special areas of research include ordinary and partial differential equations; probability; real, complex, harmonic, functional, and numerical analysis; differential and algebraic geometry; topology; number theory; commutative algebra; group theory; logic; combinatorics; mathematical physics; and applied and industrial mathematics, mathematical biology, and dynamical systems.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

Undergraduate degree in mathematics or equivalent.

Other requirements to be completed before admission:
Applicants should have the prerequisite material of linear algebra, advanced calculus and differential equations, and should be ready for higher level courses in analysis and algebra. The GRE Math subject test is strongly recommended. To receive full consideration for financial support, international applicants should have a TOEFL score of at least 100 with a speaking score of at least 23.

Special Application Requirements:
Applications are accepted for fall semester only. The application deadline is February 1. Additional information is available at math.umn.edu/graduate.

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Internet Based - Speaking Score: 18

Key to test abbreviations (TOEFL).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.
Program Requirements

Plan A: Plan A requires 14 major credits, 6 credits outside the major, and 10 thesis credits. The final exam is oral.

Plan B: Plan B requires 15 to 30 major credits and 0 to 15 credits outside the major. The final exam is oral.

This program may be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 3.00 is required for students to remain in good standing.

Plan A
Plan A requires 14 credits in mathematics courses, 6 credits in a minor or related field, and 10 thesis credits. One sequence of two 8xxx-level mathematics courses in the student’s concentration area must be included.

Thesis Credits
- Take a minimum of 10 credits
  - MATH 8777 - Thesis Credits: Master’s (1.0 - 18.0 cr)

Plan B
Plan B allows more breadth; students complete a minimum of 30 course credits, half of which may be in a related area outside of Mathematics. Mathematics courses outside the student's major research area may be used toward the related field requirement.
Twin Cities Campus
Mathematics Minor
School of Mathematics
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
School of Mathematics, University of Minnesota, 127 Vincent Hall, 206 Church Street SE, Minneapolis, MN 55455 (612-624-6391, fax: 612-624-6702)
Email: gradprog@math.umn.edu
Website: http://www.math.umn.edu/grad/

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The School of Mathematics offers a minor for both the master's and the PhD.

Special areas of research include ordinary and partial differential equations; probability; real, complex, harmonic, functional, and numerical analysis; differential and algebraic geometry; topology; number theory; commutative algebra; group theory; logic; combinatorics; mathematical physics; and applied and industrial mathematics, mathematical biology, and dynamical systems.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

The master's minor requires a minimum of 6 credits, consisting of two 5xxx- or 8xxx-level courses.

The PhD minor requires a minimum of 12 credits, consisting of four 5xxx- or 8xxx-level courses.

Courses must be completed with a grade of B or higher to satisfy the requirements. We recommend that you consult the director of graduate studies in Mathematics in advance for course approval.

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Masters Minor
Minor requires two 5xxx- or 8xxx-level mathematics courses. Minor programs must be approved by the director of graduate studies in the School of Mathematics.

Doctoral Minor
Minor requires four 5xxx- or 8xxx-level mathematics courses. Minor programs must be approved by the director of graduate studies in
the School of Mathematics.
Twin Cities Campus
Mathematics Ph.D.
School of Mathematics
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
127 Vincent Hall, 206 Church Street SE, Minneapolis, MN 55455 (612-624-6391; fax: 612-624-6702)
Email: gradprog@math.umn.edu
Website: http://www.math.umn.edu/grad/

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 60
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The School of Mathematics offers a PhD in mathematics, and a PhD in mathematics with emphasis in applied mathematics.

Special areas of research include ordinary and partial differential equations; probability: real, complex, harmonic, functional, and numerical analysis; differential and algebraic geometry; topology; number theory; commutative algebra; group theory; logic; combinatorics; mathematical physics; and applied and industrial mathematics, mathematical biology, and dynamical systems.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

Undergraduate degree in mathematics or equivalent.

Other requirements to be completed before admission:
Applicants should have the prerequisite material of abstract algebra, analysis, and topology. The GRE Math subject test is strongly recommended. To receive full consideration for financial support, international applicants should have a TOEFL score of at least 100 with a speaking score of at least 23.

Special Application Requirements:
Applications are accepted for fall semester only. The application deadline is December 15. Additional information is available at math.umn.edu/graduate.

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Internet Based - Speaking Score: 18

Key to test abbreviations (TOEFL).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
24 credits are required in the major.
12 credits are required outside the major. 
24 thesis credits are required. 
This program may be completed with a minor. 
Use of 4xxx courses towards program requirements is not permitted. 
Language Requirement: French, German, Italian, or Russian 
A minimum GPA of 3.00 is required for students to remain in good standing. 
The PhD requires 24 credits in mathematics courses, 12 credits in a minor or in a supporting program, and 24 thesis credits. If a supporting program is chosen, it may consist partly or entirely of mathematics courses outside the student’s major research area. 
Students choose a program of coursework in consultation with their advisor and the director of graduate studies. 
The PhD preliminary written examination, given twice each year, covers real analysis, complex analysis, algebra, and manifolds and topology. Students are expected to pass the written exam by the end of their second year; complete required coursework and pass the preliminary oral exam by the end of their fourth year; and pass the final oral exam and complete their dissertation by the end of the sixth year. 
Reading proficiency is required in one of the following: French, German, Italian, or Russian 

**Thesis Credits**
Take 24 credits after passing preliminary oral exam. 
**MATH 8888** - Thesis Credit: Doctoral (1.0 - 24.0 cr)
Twin Cities Campus
Mechanical Engineering M.S.M.E.
Mechanical Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Mechanical Engineering and Industrial Engineering Graduate Programs, University of Minnesota, 1120 Mechanical Engineering, 111 Church Street S.E., Minneapolis, MN 55455 (612-625-2009; fax: 612-624-2010)
Email: gardn032@umn.edu, hogan108@umn.edu
Website: http://www.me.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Science in Mechanical Engineering

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Coursework and research for all graduate degrees are offered in bioengineering; biomechanics; combustion; computer-aided design; computer-aided manufacturing; computer graphics; control systems; design; energy conservation; environmental control; environmental engineering; fluid mechanics; heat and mass transfer; history of science and technology; human factors engineering; industrial engineering; innovative methodologies; integration of structural and environmental systems; lubrication; manufacturing engineering; particle technology; plasma chemistry; plasma heat transfer; power, propulsion, and applied thermodynamics; socioeconomic systems; solar energy; solar processing and thermochemistry; statistics; structures; systems dynamics; technology assessment; thermal energy storage; thermal environmental engineering; thermodynamics; transportation; tribology; vibration; and interdisciplinary finite element methodology. Additional instructional and research programs can be formulated.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A four-year BS degree in engineering, science, or mathematics.

Special Application Requirements:
The department offers two options for applying to the masters degree program. The standard application requires a full set of application materials and allows admission to any of the MSME degree options (Plan A, B, or C). The streamlined application offers an abbreviated application process and admission is only for the coursework-only masters degree (Plan C).

The GRE test is not required for applicants to the streamlined application. Students admitted through the streamlined process are not eligible for financial support from the department.

Applications are accepted for fall semester only. The standard application deadline is December 15 and the streamlined application deadline is April 15. Additional information is available at www.me.umn.edu/education/graduate/prospective/

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
Program Requirements

Plan A: Plan A requires 14 major credits, 6 credits outside the major, and 10 thesis credits. The final exam is oral.

Plan B: Plan B requires 14 major credits and 16 credits outside the major. The final exam is oral.

Plan C: Plan C requires 24 major credits and 6 credits outside the major. There is no final exam.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with advisor approval.

A minimum GPA of 2.8 is required for students to remain in good standing.

The MSME requires a minimum of 30 credits and is offered under Plan A (thesis), Plan B (project), and Plan C (coursework only). All three plans require completion of 1-2 graduate seminar credits and one research and professional ethics course. All courses, with the exception of seminars and the ethics course, must be taken on an A/F basis.

Major Course Credits

Any 5xxx or 8xxx level mechanical engineering course counts toward the major field credit requirement, with the exception of independent research courses. The following courses also meet the requirement for ME graduate course credits.

- AEM 5401 - Intermediate Dynamics (3.0 cr)
- AEM 5501 - Continuum Mechanics (3.0 cr)
- AEM 8201 - Fluid Mechanics I (3.0 cr)
- AEM 8202 - Fluid Mechanics II (3.0 cr)
- EE 5231 - Linear Systems and Optimal Control (3.0 cr)
- EE 8215 - Nonlinear Systems (3.0 cr)

Ethics Course

Take one research and professional ethics course. The following may be used or consult with advisor for further options.

- ME 8001 - Research Ethics and Professional Practice (0.0 cr)

Seminar

Take 1-2 seminar credits. The following may be used or consult with advisor for further options.

- ME 8773 - Graduate Seminar (1.0 cr)
- ME 8774 - Graduate Seminar (1.0 cr)

Supporting Program

The remaining course credits may be taken in the major or in any supporting field with significant scientific or engineering content, and may include 6 credits in a minor.

Use of 4xxx-level Courses

No more than six 4xxx-level course credits may be used for graduate-level credit. Only the following courses are acceptable.

- AEM 4511 - Mechanics of Composite Materials (3.0 cr)
- AEM 4581 - Mechanics of Solids (3.0 cr)
- CHEM 4502 - Introduction to Quantum Mechanics and Spectroscopy (3.0 cr)
- EE 4541 - Digital Signal Processing (3.0 cr)
- MATH 4512 - Differential Equations with Applications (3.0 cr)
- PHYS 4051 - Methods of Experimental Physics I (5.0 cr)
- PHYS 4101 - Quantum Mechanics (4.0 cr)
- PHYS 4201 - Statistical and Thermal Physics (3.0 cr)
- PHYS 4211 - Introduction to Solid-State Physics (3.0 cr)

Plan A

Requires 14 credits in the major, 6 additional graduate level credits, and 10 thesis credits.

- ME 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)
Plan B
Requires 14 credits in the major, 16 additional graduate level credits, plus completion of a project or 1-3 Plan B papers, determined in consultation with the advisor. Up to 4 credits of ME 8794, taken S/N, may be used for the Plan B project.
ME 8794 - Mechanical Engineering Research (1.0 - 4.0 cr)

Plan C
Requires 24 credits in the major and 6 additional graduate level credits. Up to 4 credits of ME 8794, taken S/N, may be applied to the degree requirements.
ME 8794 - Mechanical Engineering Research (1.0 - 4.0 cr)

Program Sub-plans
A sub-plan is not required for this program.
Students may not complete the program with more than one sub-plan.

Integrated B.M.E./M.S.M.E.
The Department of Mechanical Engineering offers an integrated bachelor's/master's degree program. The program makes it possible for students to earn a bachelor's degree (BME) and a master's degree (MSME) in Mechanical Engineering in five years. The program has several benefits: a streamlined admissions process from the undergraduate program to the graduate program; graduate student status granted in the senior year; eligibility for teaching and research assistantships; and flexibility in fulfilling required courses for both degrees simultaneously in the last two years of study.

Both the BME and MSME degrees must be completed in their entirety, with no courses shared between them. The graduate degree cannot be earned before the undergraduate requirements are satisfied. Admitted students who decide not to complete the MSME degree are permitted to count credits originally planned for the graduate program toward their undergraduate technical electives.

Eligibility Requirements:
- Students must be enrolled in the Mechanical Engineering undergraduate program at the University of Minnesota, Twin Cities.
- Students who are within 32 semester credits completing the requirements for the BME degree are eligible to apply.
- Students with a GPA of 3.25 or greater are preferred. For students who have transferred from another institution, at least one semester must be completed at the University of Minnesota, Twin Cities before admission to the program will be granted.
Twin Cities Campus
Mechanical Engineering Minor
Mechanical Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Mechanical Engineering and Industrial Engineering Graduate Programs, University of Minnesota, 1120 Mechanical Engineering, 111 Church Street S.E., Minneapolis, MN 55455 (612-625-2009; fax: 612-624-2010)
Email: gardn032@umn.edu, hogan108@umn.edu
Website: http://www.me.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Coursework and research for all graduate degrees are offered in bioengineering; biomechanics; combustion; computer-aided design; computer-aided manufacturing; computer graphics; control systems; design; energy conservation; environmental control; environmental engineering; fluid mechanics; heat and mass transfer; history of science and technology; human factors engineering; industrial engineering; innovative methodologies; integration of structural and environmental systems; lubrication; manufacturing engineering; particle technology; plasma chemistry; plasma heat transfer; power, propulsion, and applied thermodynamics; socioeconomic systems; solar energy; solar processing and thermochemistry; statistics; structures; systems dynamics; technology assessment; thermal energy storage; thermal environmental engineering; thermodynamics; transportation; tribology; vibration; and interdisciplinary finite element methodology. Additional instructional and research programs can be formulated.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

Mechanical engineering courses at the 5xxx or 8xxx level may be used for the minor, with the following exceptions: ME 8773, ME 8774, and ME 8794.

Program Sub-plans
Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

Master's Minor
At least 6 credits in mechanical engineering are required for a master's minor.

Doctoral Minor
At least 12 credits in mechanical engineering are required for a doctoral minor.

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
Twin Cities Campus
Mechanical Engineering Ph.D.
Mechanical Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Mechanical Engineering and Industrial Engineering Graduate Programs, University of Minnesota, 1120 Mechanical Engineering, 111 Church Street S.E., Minneapolis, MN 55455 (612-625-2009; fax: 612-624-2010)
Email: gardn032@umn.edu, hogan108@umn.edu
Website: http://www.me.umn.edu

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 62
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Coursework and research for all graduate degrees are offered in bioengineering; biomechanics; combustion; computer-aided design; computer-aided manufacturing; computer graphics; control systems; design; energy conservation; environmental control; environmental engineering; fluid mechanics; heat and mass transfer; history of science and technology; human factors engineering; industrial engineering; innovative methodologies; integration of structural and environmental systems; lubrication; manufacturing engineering; particle technology; plasma chemistry; plasma heat transfer; power, propulsion, and applied thermodynamics; socioeconomic systems; solar energy; solar processing and thermochemistry; statistics; structures; systems dynamics; technology assessment; thermal energy storage; thermal environmental engineering; thermodynamics; transportation; tribology; vibration; and interdisciplinary finite element methodology. Additional instructional and research programs can be formulated.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A four-year BS degree in engineering, science, or mathematics.

Special Application Requirements:
Applications are accepted for fall semester only. The application deadline is December 15. Additional information is available at www.me.umn.edu/education/graduate/prospective/

Applicants must submit their test score(s) from the following:
- GRE

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
- Paper Based - Total Score: 550
- IELTS
  - Total Score: 6.5

Key to test abbreviations (GRE, TOEFL, IELTS).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.
Program Requirements
18 credits are required in the major.
20 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.0 is required for students to remain in good standing.

The PhD requires a minimum of 38 course credits, consisting of 18 credits in the major and 20 additional graduate level credits. Courses must be taken on an A/F basis, with the exception of seminars and the ethics course. A minimum of 12 course credits at the 8000-level are required (seminars and ethics courses may not be included). Students must complete 2-3 graduate seminar credits, and one research and professional ethics course. 24 thesis credits are also required.

Major Course Credits
Take 18 credits in any 5xxx or 8xxx level mechanical engineering courses. Independent research courses do not count toward the credit requirement. The following courses also meet the requirement for ME graduate course credits.

- AEM 5401 - Intermediate Dynamics (3.0 cr)
- AEM 5501 - Continuum Mechanics (3.0 cr)
- AEM 8201 - Fluid Mechanics I (3.0 cr)
- AEM 8202 - Fluid Mechanics II (3.0 cr)
- EE 5231 - Linear Systems and Optimal Control (3.0 cr)
- EE 8215 - Nonlinear Systems (3.0 cr)

Ethics Course
Take one research and professional ethics course. The following may be used or consult with advisor for further options.

- ME 8001 - Research Ethics and Professional Practice (0.0 cr)

Seminar
Take 2-3 seminar credits. The following may be used or consult with advisor for further options.

- ME 8773 - Graduate Seminar (1.0 cr)
- ME 8774 - Graduate Seminar (1.0 cr)

Supporting Program
The remaining course credits may be taken in the major or in any supporting field with significant scientific or engineering content, and may include 12 credits in a minor.

Thesis Credits
Take 24 thesis credits after passing the preliminary oral exam.

- ME 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)

Use of 4xxx-level Courses
No more than six 4xxx-level course credits may be used for graduate-level credit. Only the following courses are acceptable.

- AEM 4511 - Mechanics of Composite Materials (3.0 cr)
- AEM 4581 - Mechanics of Solids (3.0 cr)
- CHEM 4502 - Introduction to Quantum Mechanics and Spectroscopy (3.0 cr)
- EE 4541 - Digital Signal Processing (3.0 cr)
- MATH 4512 - Differential Equations with Applications (3.0 cr)
- PHYS 4051 - Methods of Experimental Physics I (5.0 cr)
- PHYS 4101 - Quantum Mechanics (4.0 cr)
- PHYS 4201 - Statistical and Thermal Physics (3.0 cr)
- PHYS 4211 - Introduction to Solid-State Physics (3.0 cr)
Twin Cities Campus
Medical Device Innovation M.S.
Technological Leadership Institute
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Technological Leadership Institute, College of Science and Engineering, University of Minnesota, Suite 290 McNamara Alumni Center, 200 Oak Street SE, Minneapolis MN 55455
Phone: 612-624-5747
Fax: 612-624-7510
Email: mdi@umn.edu
Website: http://www.tli.umn.edu

• Program Type: Master's
• Requirements for this program are current for Fall 2018
• Length of program in credits: 34
• This program does not require summer semesters for timely completion.
• Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The master of science in medical device innovation (MDI) program is an interdisciplinary program administered by the College of Science and Engineering's Technological Leadership Institute (TLI). The program is comprised of courses in the core areas of technology innovation management and medical industry dynamics. Students experiences are enhanced through therapeutic area-based group activities and hands-on experiences in innovative biodesign through practicums at the Medical Devices Center. Students have the opportunity to specialize in an area of interest by taking 9 credits of electives in medical, technical, or business courses. The 14-month program draws upon the fields of technology innovation, product development, project and business management, intellectual property, regulatory affairs, clinical needs, entrepreneurship, emerging trends, globalization, reimbursement, and public policy. This program provides students with a full understanding of medical device innovation from start to finish. In doing so, it goes well beyond the traditional technology focus of most master's programs.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A bachelor's degree in a related field, such as biological or physical sciences, engineering, computer science, mathematics, or statistics.

Other requirements to be completed before admission:
Strong background in science, engineering, and math, with at least two to five years of work experience.

Special Application Requirements:
Applications are accepted on a rolling basis for the program's start in the summer of each year. The deadline for international students is March 15. Additional information is available at mdi.umn.edu.

International applicants must submit score(s) from one of the following tests:
• TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
• IELTS
  - Total Score: 6.5
The preferred English language test is Test of English as Foreign Language.

Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

Plan B: Plan B requires 28 major credits and 6 credits outside the major. The final exam is written and oral. A capstone project is required.

Capstone Project: The capstone project is independent, original, and applied research on a relevant subject, problem, or issue in areas of medical device technologies, policy, business, or innovation. The capstone project is rooted in real-world topics in the industry, and is usually framed in cooperation with the students organization or employer. The capstone is the students opportunity to demonstrate mastery of the concepts and methods (quantitative as well as qualitative) that have been learned in the MDI program, and to apply them to an industry-based medical device technology, venture, process, or organizational challenge.

This program may be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 3.25 is required for students to remain in good standing.

Core Courses (26 Credits)

Take the following courses for a total of 26 credits. Take MDI for 1 credit.

MDI 5001 - Technical Writing Essentials (0.0 - 1.0 cr)
MDI 5002 - Technology Foresight and Forecasting (3.0 cr)
MDI 5004 - Clinical Foundations of Medical Device Innovation (3.0 cr)
MDI 5006 - Finance, Valuation, and Entrepreneurship (3.0 cr)
MDI 5008 - Quality, Regulatory and Manufacturing Management (2.0 cr)
MDI 5010 - Product Innovation & Development Management (3.0 cr)
MDI 5012 - Medical Industry Macro Environment (3.0 cr)
MDI 5013 - Medical Device Center Practicum I (2.0 cr)
MDI 5014 - Medical Device Center Practicum II (2.0 cr)
MDI 5015 - Medical Device Center Practicum III (2.0 cr)
MDI 5050 - Interpersonal & Team Effectiveness (1.0 cr)
MDI 5051 - Leading Innovation & Change (1.0 cr)

Electives (6 Credits)

Take six credits of electives from the following list. Other courses may be selected in consultation with the director of graduate studies.

ABUS 4043 - Project Management in Practice (3.0 cr)
ABUS 4509 - New Product Development (3.0 cr)
BMEN 5001 - Advanced Biomaterials (3.0 cr)
BMEN 5041 - Tissue Engineering (3.0 cr)
BMEN 5101 - Advanced Bioelectricity and Instrumentation (3.0 cr)
BMEN 5151 - Introduction to BioMEMS and Medical Microdevices (2.0 cr)
BMEN 5201 - Advanced Biomechanics (3.0 cr)
BMEN 5311 - Advanced Biomedical Transport Processes (3.0 cr)
BMEN 5321 - Microfluidics in Biology and Medicine (3.0 cr)
BMEN 5351 - Cell Engineering (3.0 cr)
BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
BMEN 5411 - Neural Engineering (3.0 cr)
BMEN 5412 - Neuromodulation (3.0 cr)
BMEN 5413 - Neural Decoding and Interfacing (3.0 cr)
BMEN 5421 - Introduction to Biomedical Optics (3.0 cr)
BMEN 5501 - Biology for Biomedical Engineers (3.0 cr)
BMEN 5701 - Cancer Bioengineering (3.0 cr)
BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
BTHX 5100 - Introduction to Clinical Ethics (3.0 cr)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTHX 5210</td>
<td>Ethics of Human Subjects Research</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BTHX 5300</td>
<td>Foundations of Bioethics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BTHX 5325</td>
<td>Biomedical Ethics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BTHX 5400</td>
<td>Intro Ethics in Hlth Policy</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BTHX 5411</td>
<td>Health Law and Policy</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BTHX 5453</td>
<td>Law, Biomedicine, and Bioethics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BTHX 5610</td>
<td>Research &amp; Publication Seminar</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>BTHX 5620</td>
<td>Social Context of Health and Illness</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BTHX 8114</td>
<td>Ethical and legal Issues in Genetic Counseling</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BTHX 8510</td>
<td>Gender and the Politics of Health</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>BTHX 8610</td>
<td>Medical Consumerism</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5103</td>
<td>Operating Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5105</td>
<td>Introduction to Distributed Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5115</td>
<td>User Interface Design, Implementation and Evaluation</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5143</td>
<td>Real-Time and Embedded Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5204</td>
<td>Advanced Computer Architecture</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5211</td>
<td>Data Communications and Computer Networks</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5221</td>
<td>Foundations of Advanced Networking</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5231</td>
<td>Wireless and Sensor Networks</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5451</td>
<td>Introduction to Parallel Computing: Architectures, Algorithms, and Programming</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5461</td>
<td>Functional Genomics, Systems Biology, and Bioinformatics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5481</td>
<td>Computational Techniques for Genomics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5523</td>
<td>Introduction to Data Mining</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5551</td>
<td>Introduction to Intelligent Robotic Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5552</td>
<td>Sensing and Estimation in Robotics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5509</td>
<td>Visualization</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5707</td>
<td>Principles of Database Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5708</td>
<td>Architecture and Implementation of Database Management Systems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5801</td>
<td>Software Engineering I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 5802</td>
<td>Software Engineering II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>CSCI 8725</td>
<td>Databases for Bioinformatics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>DES 5185</td>
<td>Human Factors in Design</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5121</td>
<td>Transistor Device Modeling for Circuit Simulation</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5141</td>
<td>Introduction to Microsystem Technology</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 5163</td>
<td>Semiconductor Properties and Devices I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5164</td>
<td>Semiconductor Properties and Devices II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5171</td>
<td>Microelectronic Fabrication</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>EE 5181</td>
<td>Micro and Nanotechnology by Self Assembly</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5251</td>
<td>Optimal Filtering and Estimation</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5364</td>
<td>Advanced Computer Architecture</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5371</td>
<td>Computer Systems Performance Measurement and Evaluation</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5393</td>
<td>Circuits, Computation, and Biology</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5542</td>
<td>Adaptive Digital Signal Processing</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5545</td>
<td>Digital Signal Processing Design</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5551</td>
<td>Multiscale and Multirate Signal Processing</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5581</td>
<td>Information Theory and Coding</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5583</td>
<td>Error Control Coding</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 5585</td>
<td>Data Compression</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>EE 8367</td>
<td>Parallel Computer Organization</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>ENTR 6020</td>
<td>Business Formation</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>HINF 5502</td>
<td>Python Programming Essentials for the Health Sciences</td>
<td>1.0 cr</td>
</tr>
<tr>
<td>HINF 5510</td>
<td>Applied Health Care Databases: Database Principles and Data Evaluation</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>HINF 5520</td>
<td>Informatics Methods for Health Care Quality, Outcomes, and Patient Safety</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>HINF 5530</td>
<td>Health Care Software Management</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>HINF 5531</td>
<td>Health Data Analytics and Data Science</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>IE 5111</td>
<td>Systems Engineering I</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>IE 5113</td>
<td>Systems Engineering II</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>IE 5522</td>
<td>Quality Engineering and Reliability</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>IE 5541</td>
<td>Project Management</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>IE 5545</td>
<td>Decision Analysis</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>IE 5551</td>
<td>Production Planning and Inventory Control</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>IE 5553</td>
<td>Simulation</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>IMBA 6405</td>
<td>Industry Vertical: Health</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>MBA 6110</td>
<td>Leading Others</td>
<td>2.0 cr</td>
</tr>
<tr>
<td>MBA 6300</td>
<td>Strategic Management</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Credits</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>ME 5223</td>
<td>Materials in Design (4.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ME 5341</td>
<td>Case Studies in Thermal Engineering and Design (4.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ME 8262</td>
<td>Topics in Modeling and Analysis of Manufacturing Processes (4.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ME 8381</td>
<td>Bioheat and Mass Transfer (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ME 8775</td>
<td>Technical Communication (1.0 cr)</td>
<td></td>
</tr>
<tr>
<td>MG 5050</td>
<td>Management of Innovation and Change (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>MG 6100</td>
<td>Topics in Management (1.0 - 4.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ML 6235</td>
<td>Pharmaceutical Industry: Business and Policy (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ML 6562</td>
<td>Information Technology in Health Care (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ML 6589</td>
<td>Medical Technology Evaluation and Market Research (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ML 6726</td>
<td>Medical Device Industry: Business and Public Policy (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ML 6990</td>
<td>The Health Care Marketplace (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ML 6991</td>
<td>Anatomy and Physiology for Managers (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ML 6992</td>
<td>Healthcare Delivery Innovations: Optimizing Cost and Quality (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ML 6995</td>
<td>Medical Industry Valuation Laboratory (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ML 6988</td>
<td>Strategic Marketing (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>NE 5230</td>
<td>Cerebrovascular Hemodynamics and Diseases I (4.0 cr)</td>
<td></td>
</tr>
<tr>
<td>NE 5240</td>
<td>Cerebrovascular Hemodynamics and Diseases II (4.0 cr)</td>
<td></td>
</tr>
<tr>
<td>PE 5701</td>
<td>Creativity, Idea Generation, and Innovation (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>PE 5702</td>
<td>Concept Sketching and Rendering (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>PE 5704</td>
<td>Computer-Aided Design Methods (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>PH 5061</td>
<td>Principles of Physiology for Biomedical Engineering (4.0 cr)</td>
<td></td>
</tr>
<tr>
<td>PH 5510</td>
<td>Advanced Cardiac Physiology and Anatomy (2.0 - 3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>PH 5525</td>
<td>Anatomy and Physiology of the Pelvis and Urinary System (1.0 - 2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>PS 5055</td>
<td>Functional Imaging: Hands-on Training (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>PUB 6751</td>
<td>Principles of Management in Health Services Organizations (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>PUB 6090</td>
<td>Economics of the Health Care System (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>PUB 6862</td>
<td>Cost-Effectiveness Analysis in Health Care (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>SC 5101</td>
<td>Mathematical Tools for Research Applications in Health, Rehab, and Human Movement Sciences (1.0 cr)</td>
<td></td>
</tr>
<tr>
<td>SC 5106</td>
<td>Introduction to Rehabilitation Science (1.0 cr)</td>
<td></td>
</tr>
<tr>
<td>SC 5135</td>
<td>Advanced Biomechanics I: Kinematics (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>SC 5200</td>
<td>Introduction to Neuromodulation (1.0 - 3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>SC 5231</td>
<td>Clinical Biomechanics (2.0 - 5.0 cr)</td>
<td></td>
</tr>
<tr>
<td>SC 5281</td>
<td>Scientific Foundations: Exercise Theory (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>SC 8181</td>
<td>Stem Cell Biology (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ST 8109</td>
<td>Cybersecurity Foundations - Technology, Risk &amp; Communication (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ST 8800</td>
<td>Security Science and Technology Foundations (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ST 8111</td>
<td>Methods, Theory, and Applications (2.5 cr)</td>
<td></td>
</tr>
<tr>
<td>ST 8113</td>
<td>Information and Cyber Security (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ST 8220</td>
<td>Vulnerability, Risk and Threat Assessment and Management (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ST 8330</td>
<td>Critical Infrastructure Protections (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ST 8331</td>
<td>Dynamic Systems Modeling and Simulation Tools (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ST 8513</td>
<td>Cyber Threat Intelligence (2.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ST 8661</td>
<td>Securing Cyberspace (Fundamentals) (3.0 cr)</td>
<td></td>
</tr>
<tr>
<td>ST 8662</td>
<td>Securing Cyberspace - Advanced (3.0 cr)</td>
<td></td>
</tr>
</tbody>
</table>

Students may choose a minor in human factors and ergonomics, but must have courses pre-approved by the director of graduate studies.

**Capstone Project (2 Credits)**

Take 2 credits of MDI 5020.

**MDI 5020** - Medical Device Innovation Capstone (1.0 - 2.0 cr)
Twin Cities Campus  
Neuroengineering Minor  
Department of Biomedical Engineering  
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:  
Graduate Minor in Neuroengineering, 7-105 Nils Hasselmo Hall, 312 Church Street S.E., Minneapolis, MN 55455 (612-624-8396; fax 612-626-6583)  
Email: bmengp@umn.edu  
Website: http://neuroengineering.umn.edu/

- Program Type: Graduate free-standing minor  
- Requirements for this program are current for Fall 2018  
- Length of program in credits (Doctorate): 12  
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The graduate minor in neuroengineering (NE) is motivated by the notion that future breakthroughs in this rapidly-growing area of research will be made by engineers who understand the fundamental issues and principles of neuroscience that occur during neural interventions, and by neuroscientists who are truly competent in engineering concepts and tools. The minor trains doctoral students to develop the skills to revolutionize technologies for interfacing with the brain and to advance our understanding of the neuroscience processes that arise when we interface with and modulate the brain.

Program Delivery
This program is available:  
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
Other requirements to be completed before admission:  
Enrollment in the neuroengineering minor is open to all currently enrolled PhD students in biomedical engineering, electrical engineering, mechanical engineering, and neuroscience. PhD students majoring in other programs may obtain approval from the neuroengineering director of graduate studies to participate in the minor program if they have the necessary science background to complete the coursework and are in good standing in their major program.

Students must officially declare the minor before taking the Oral Preliminary Examination (OPE).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

Coursework must be approved by the neuroengineering director of graduate studies (DGS) - see http://neuroengineering.umn.edu/faculty.html.

For any course listed in multiple categories, students must choose which requirement that course will fulfill. A single course cannot be counted simultaneously toward multiple categories. The only exception is BMEn 8411 Neuroengineering Seminar, which must be taken once for the Seminar requirement and can be taken a second time to count as an Elective.

Students may not use any of their minor courses to satisfy the core course requirements for their major program (i.e., a Neuroscience student cannot count NSC 5561 as both a Neuroengineering Minor course and a core Neuroscience course).

Neuroengineering Seminar
BMEN 8411 - Neuroengineering Seminar (2.0 cr)
Engineering Core
It is strongly recommended that students take BMEn 5411 Neural Engineering, unless they have previously completed a neural engineering course. The Engineering Core course must be completed for a letter grade (A-F), and a minimum grade of B- is required for the course to count toward the minor.
Take 1 or more course(s) from the following:
- BMEN 5411 - Neural Engineering (3.0 cr)
- BMEN 5412 - Neuromodulation (3.0 cr)

Neuroscience Core
The Neuroscience Core course must be completed for a letter grade (A-F), and a minimum grade of B- is required for the course to count toward the minor.
Take 1 or more course(s) from the following:
- NSCI 5101 - Neurobiology I: Molecules, Cells, and Systems (3.0 cr)
- NSC 5561 - Systems Neuroscience (4.0 cr)

Electives
Additional coursework in engineering or neuroscience discipline is required - students must take enough elective credits to reach a total of 12 minimum for the minor. Additional courses may be approved as electives by the neuroengineering DGS. Elective Courses must be completed for a letter grade (A-F), and a minimum grade of B- is required for the course(s) to count toward the minor.
Take 1 or more course(s) from the following:
- BMEN 5401 - Advanced Biomedical Imaging (3.0 cr)
- BMEN 5411 - Neural Engineering (3.0 cr)
- BMEN 5412 - Neuromodulation (3.0 cr)
- BMEN 5413 - Neural Decoding and Interfacing (3.0 cr)
- BMEN 8101 - Biomedical Digital Signal Processing (3.0 cr)
- BMEN 8151 - Biomedical Electronics and Implantable Microsystems (3.0 cr)
- BMEN 8502 - Physiological Control Systems (3.0 cr)
- EE 5231 - Linear Systems and Optimal Control (3.0 cr)
- EE 5239 - Introduction to Nonlinear Optimization (3.0 cr)
- EE 5542 - Adaptive Digital Signal Processing (3.0 cr)
- ME 5281 - Analog and Digital Control (4.0 cr)
- ME 5286 - Robotics (4.0 cr)
- MPH 5178 - Physical Principles of Magnetic Resonance Imaging (3.0 cr)
- MPH 8147 - Advanced Physics of Magnetic Resonance Imaging (MRI) (3.0 cr)
- NSC 8111 - Quantitative Neuroscience (3.0 cr)
- NSC 8217 - Systems and Computational Neuroscience (2.0 cr)
- PSY 5036W - Computational Vision [WI] (3.0 cr)
- PSY 5038W - Introduction to Neural Networks [WI] (3.0 cr)
- PSY 5063 - Introduction to Functional MRI (3.0 cr)
- PSY 5065 - Functional Imaging: Hands-on Training (3.0 cr)

Program Sub-plans
Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Doctoral
Twin Cities Campus

Physics M.S.

School of Physics & Astronomy

College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Director of Graduate Studies in Physics, School of Physics and Astronomy, University of Minnesota, 116 Church St. SE, Minneapolis, MN 55455 (612-626-5982; fax: 612-624-4578)
Email: grad@physics.umn.edu
Website: http://www.physics.umn.edu/grad

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Science

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Note: Students applying for a terminal MS degree are not admitted, unless they arrange for their own financial support. Students admitted to the PhD program are automatically eligible for the MS program.

Physics is the study of the fundamental structure and interactions of matter. Research areas in the program include experimental and theoretical studies in astrophysics and cosmology, biological physics, condensed matter physics, elementary particle physics, nuclear physics, space and planetary physics, and physics education research. Interdisciplinary study is also available with the programs in astrophysics, biological sciences, chemistry, chemical engineering and materials science, electrical and computer engineering, mechanical engineering, and the history of science and technology.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.30.

Other requirements to be completed before admission:
Upper division courses in the core areas of classical mechanics, electricity and magnetism, quantum mechanics, and statistical and thermal physics are required. It is advisable to have taken an upper division course in experimental methods in physics.

Special Application Requirements:
Students admitted to the Ph.D. program are automatically eligible for the M.S. program. Students applying for a terminal M.S. degree are not admitted unless they arrange for their own financial support.

Applications are accepted for fall admission only. Application by December 15 is strongly encouraged. Additional application information is available at http://www.physics.umn.edu/grad/physics/application.html

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80
Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

Plan A: Plan A requires 20 major credits, 0 credits outside the major, and 10 thesis credits. The final exam is oral.

Plan B: Plan B requires 30 major credits and 0 credits outside the major. The final exam is oral. A capstone project is required.

Capstone Project: The Plan B project is a self-contained research problem performed in conjunction with the student's advisor. Students register for 4 credits of Physics 8500: Plan B project, which count toward the program requirement of 30 credits. The project is described in a written paper. Examples of Plan B projects include carrying out a specific calculation, writing and documenting a computer program, analyzing a set of experimental data, designing and/or constructing experimental instrumentation, and designing and/or constructing an undergraduate laboratory experiment. The alternative to the Plan B project is writing 1-3 Plan B papers. The Plan B papers are related to three courses that the student has taken and do not require original research. It's expected that completion of either the project or the Plan B papers require a nominal three weeks of full-time effort.

Plan C: Plan C requires 30 major credits and 0 credits outside the major. The final exam is oral. This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

Physics 4001, 4002, 4101, 4201, and 4303 cannot be used to satisfy degree requirements.

To remain in good academic standing students must maintain a minimum GPA of 3.30.

Students completing the Plan C option must also pass the physics graduate written exam.

Required Courses

Plan A and Plan B students must complete either the quantum mechanics sequence or the classical physics sequence. Plan C students must complete both sequences.

Quantum Mechanics Sequence
- PHYS 5001 - Quantum Mechanics I (4.0 cr)
- PHYS 5002 - Quantum Mechanics II (4.0 cr)

Classical Physics Sequence
- PHYS 5011 - Classical Physics I (4.0 cr)
- PHYS 5012 - Classical Physics II (4.0 cr)

Plan A
Plan A requires 8 credits in a required sequence and an additional 12 course credits taken in the major or in a related field, including in a minor. Ten thesis credits are also required.

PHYS 8777 - Thesis Credits: Master's (1.0 - 18.0 cr)

Plan B
Plan B requires 8 credits in a required sequence and an additional 22 course credits taken in the major or in a related field, including in a minor. Up to 4 credits of PHYS 8500 may be used for the Plan B project.

PHYS 8500 - Plan B Project (4.0 cr)

Plan C
Plan C requires the two course sequences listed above (16 credits) and PHYS 5201 (3 credits). The remaining 11 credits may be taken in the major field or in a related field, including in a minor.

PHYS 5201 - Thermal and Statistical Physics (3.0 cr)

Electives
Students may choose courses from this list or consult with their advisor for additional options.

Atomic Physics and Optics
- PHYS 8161 - Atomic and Molecular Structure (3.0 cr)

Biophysics and Medical Physics
- PHYS 5081 - Introduction to Biopolymer Physics (3.0 cr)
- PHYS 5401 - Physiological Physics (4.0 cr)
PHYS 5402 - Radiological Physics (4.0 cr)
PHYS 8311 - Biological Physics of Single Molecules (3.0 cr)
PHYS 8312 - Biological Physics of Macroscopic Systems (3.0 cr)
PHYS 8300 - Seminar: Biological and Medical Physics. (1.0 cr)

**Condensed Matter Physics**
PHYS 4211 - Introduction to Solid-State Physics (3.0 cr)
PHYS 5701 - Solid-State Physics for Engineers and Scientists (4.0 cr)
PHYS 8702 - Statistical Mechanics and Transport Theory (3.0 cr)
PHYS 8711 - Solid-State Physics I (3.0 cr)
PHYS 8712 - Solid-State Physics II (3.0 cr)
PHYS 8750 - Advanced Topics in Condensed Matter Physics (3.0 cr)
PHYS 8700 - Seminar: Condensed Matter Physics (1.0 cr)

**Elementary Particle Physics**
PHYS 4511 - Introduction to Nuclear and Particle Physics (3.0 cr)
PHYS 8011 - Quantum Field Theory I (3.0 cr)
PHYS 8012 - Quantum Field Theory II (3.0 cr)
PHYS 8013 - Special Topics in Quantum Field Theory (3.0 cr)
PHYS 8901 - Elementary Particle Physics I (3.0 cr)
PHYS 8902 - Elementary Particle Physics II (3.0 cr)
PHYS 8911 - Introduction to Supersymmetry (3.0 cr)
PHYS 8950 - Advanced Topics in Elementary Particle Physics (3.0 cr)
PHYS 8900 - Seminar: Elementary Particle Physics (1.0 cr)

**Mathematical, Advanced Quantum, and Computational Physics**
PHYS 5041 - Mathematical Methods for Physics (4.0 cr)
PHYS 8001 - Advanced Quantum Mechanics (3.0 cr)
PHYS 8301 - Symmetry and Its Application to Physical Problems (3.0 cr)

**Nuclear Physics**
PHYS 8800 - Seminar: Nuclear Physics (1.0 cr)
PHYS 8801 - Nuclear Physics I (3.0 cr)
PHYS 8802 - Nuclear Physics II (3.0 cr)
PHYS 8850 - Advanced Topics in Nuclear Physics (3.0 cr)

**Plasma and Space Physics**
PHYS 4611 - Introduction to Space Physics (3.0 cr)
PHYS 4621 - Introduction to Plasma Physics (3.0 cr)
PHYS 8601 - Plasma Physics I (3.0 cr)
PHYS 8602 - Plasma Physics II (3.0 cr)
PHYS 8611 - Cosmic Rays and Plasma Astrophysics (3.0 cr)
PHYS 8650 - Advanced Topics in Space and Plasma Physics (3.0 cr)
PHYS 8600 - Seminar: Space Physics (1.0 cr)

**Relativity and Cosmology**
PHYS 5022 - Relativity, Cosmology, and the Universe (4.0 cr)
PHYS 8501 - General Relativity and Cosmology I (3.0 cr)
PHYS 8502 - General Relativity and Cosmology II (3.0 cr)
PHYS 8200 - Seminar: Cosmology and High Energy Astrophysics (1.0 cr)

**Physics Education**
PHYS 5072 - Best Practices in College Physics Teaching (1.0 - 3.0 cr)
PHYS 8100 - Seminar: Problems of Physics Teaching and Higher Education (1.0 cr)
Twin Cities Campus
Physics Minor
School of Physics & Astronomy
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Director of Graduate Studies in Physics, School of Physics and Astronomy, University of Minnesota, 116 Church St. SE, Minneapolis, MN 55455 (612-626-5982; fax: 612-624-4578)
Email: grad@physics.umn.edu
Website: http://www.physics.umn.edu/grad

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Physics is the study of the fundamental structure and interactions of matter. Research areas in the program include experimental and theoretical studies in astrophysics and cosmology, biological physics, condensed matter physics, elementary particle physics, nuclear physics, space and planetary physics, and physics education research. Interdisciplinary study is also available with the programs in astrophysics, biological sciences, chemistry, chemical engineering and materials science, electrical and computer engineering, mechanical engineering, and the history of science and technology.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
Other requirements to be completed before admission:
A physics minor requires a background in differential and integral calculus and one year of calculus-level college physics.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

The master's minor requires a minimum of 6 credits in PHYS courses (including 5001 or 5012).
The doctoral minor requires a minimum of 12 credits in PHYS courses (including 5001 and 5002-or-5011 and 5012).

The following courses cannot be used to satisfy the requirements: Physics 4001, 4002, 4101, 4201, and 4303.

Elective Course Options
PHYS subject requirements can be met through a combination of any of the classes listed below (minimum 2 credits for MS minor after required course and minimum 4 credits for PhD minor after required courses)

Take 2 or more credit(s) from the following:

Atomic Physics and Optics
- PHYS 8161 - Atomic and Molecular Structure (3.0 cr)

Biophysics and Medical Physics
- PHYS 5081 - Introduction to Biopolymer Physics (3.0 cr)
- PHYS 5401 - Physiological Physics (4.0 cr)
or PHYS 5402 - Radiological Physics (4.0 cr)
or PHYS 8311 - Biological Physics of Single Molecules (3.0 cr)
or PHYS 8312 - Biological Physics of Macroscopic Systems (3.0 cr)
or PHYS 8300 - Seminar: Biological and Medical Physics. (1.0 cr)

- **Condensed Matter Physics**
  - PHYS 4211 - Introduction to Solid-State Physics (3.0 cr)
  - PHYS 5701 - Solid-State Physics for Engineers and Scientists (4.0 cr)
  - PHYS 8702 - Statistical Mechanics and Transport Theory (3.0 cr)
  - PHYS 8711 - Solid-State Physics I (3.0 cr)
  - PHYS 8712 - Solid-State Physics II (3.0 cr)
  - PHYS 8750 - Advanced Topics in Condensed Matter Physics (3.0 cr)
  - PHYS 8700 - Seminar: Condensed Matter Physics (1.0 cr)

- **Elementary Particle Physics**
  - PHYS 4511 - Introduction to Nuclear and Particle Physics (3.0 cr)
  - PHYS 8011 - Quantum Field Theory I (3.0 cr)
  - PHYS 8012 - Quantum Field Theory II (3.0 cr)
  - PHYS 8013 - Special Topics in Quantum Field Theory (3.0 cr)
  - PHYS 8901 - Elementary Particle Physics I (3.0 cr)
  - PHYS 8902 - Elementary Particle Physics II (3.0 cr)
  - PHYS 8911 - Introduction to Supersymmetry (3.0 cr)
  - PHYS 8950 - Advanced Topics in Elementary Particle Physics (3.0 cr)
  - PHYS 8900 - Seminar: Elementary Particle Physics (1.0 cr)

- **Mathematical, Advanced Quantum, and Computational Physics**
  - PHYS 5041 - Mathematical Methods for Physics (4.0 cr)
  - PHYS 8001 - Advanced Quantum Mechanics (3.0 cr)
  - PHYS 8301 - Symmetry and Its Application to Physical Problems (3.0 cr)

- **Nuclear Physics**
  - PHYS 8800 - Seminar: Nuclear Physics (1.0 cr)
  - PHYS 8801 - Nuclear Physics I (3.0 cr)
  - PHYS 8802 - Nuclear Physics II (3.0 cr)
  - PHYS 8850 - Advanced Topics in Nuclear Physics (3.0 cr)

- **Plasma and Space Physics**
  - PHYS 4611 - Introduction to Space Physics (3.0 cr)
  - PHYS 4621 - Introduction to Plasma Physics (3.0 cr)
  - PHYS 8601 - Plasma Physics I (3.0 cr)
  - PHYS 8602 - Plasma Physics II (3.0 cr)
  - PHYS 8611 - Cosmic Rays and Plasma Astrophysics (3.0 cr)
  - PHYS 8650 - Advanced Topics in Space and Plasma Physics (3.0 cr)
  - PHYS 8600 - Seminar: Space Physics (1.0 cr)

- **Relativity and Cosmology**
  - PHYS 5022 - Relativity, Cosmology, and the Universe (4.0 cr)
  - PHYS 8501 - General Relativity and Cosmology I (3.0 cr)
  - PHYS 8502 - General Relativity and Cosmology II (3.0 cr)
  - PHYS 8200 - Seminar: Cosmology and High Energy Astrophysics (1.0 cr)

- **Physics Education**
  - PHYS 5072 - Best Practices in College Physics Teaching (1.0 - 3.0 cr)
  - PHYS 8100 - Seminar: Problems of Physics Teaching and Higher Education (1.0 cr)

---

**Program Sub-plans**

Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

**Masters**

Students must complete a minimum of 6 credits in physics including either Physics 5001 or 5011.

**Required Courses**

- PHYS 5001 - Quantum Mechanics I (4.0 cr)
- PHYS 5011 - Classical Physics I (4.0 cr)

**Doctoral Minor**

Students must complete a minimum of 12 credits in physics, including either the classical physics sequence or the quantum mechanics sequence.
Required Courses

Quantum Mechanics Sequence
- PHYS 5001 - Quantum Mechanics I (4.0 cr)
- PHYS 5002 - Quantum Mechanics II (4.0 cr)

or Classical Physics Sequence
- PHYS 5011 - Classical Physics I (4.0 cr)
- PHYS 5012 - Classical Physics II (4.0 cr)
Twin Cities Campus
Physics Ph.D.
School of Physics & Astronomy
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Director of Graduate Studies in Physics, School of Physics and Astronomy, University of Minnesota, 116 Church St. SE, Minneapolis, MN 55455 (612-626-5982; fax: 612-624-4578)
Email: grad@physics.umn.edu
Website: http://www.physics.umn.edu/grad

- Program Type: Doctorate
- Requirements for this program are current for Fall 2018
- Length of program in credits: 64
- This program does not require summer semesters for timely completion.
- Degree: Doctor of Philosophy

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

Physics is the study of the fundamental structure and interactions of matter. Research areas in the program include experimental and theoretical studies in astrophysics and cosmology, biological physics, condensed matter physics, elementary particle physics, nuclear physics, space and planetary physics, and physics education research. Interdisciplinary study is also available with the programs in astrophysics, biological sciences, chemistry, chemical engineering and materials science, electrical and computer engineering, mechanical engineering, and the history of science and technology.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.50.

Other requirements to be completed before admission:
Teaching assistantships and a few fellowships are available upon admittance to the School of Physics and Astronomy.

Applicants are required to submit three letters of recommendation from persons familiar with their scholarship and research potential; a complete set of transcripts; and a clearly written statement of career interests, goals, and objectives. Submission of GRE scores is strongly recommended. Fall semester entry is strongly recommended for all students. Application by December 15 is strongly encouraged to ensure priority consideration for fellowships awarded for the next academic year. Additional application information is available at http://www.physics.umn.edu/grad/physics/application.html

Special Application Requirements:
Courses at the upper division level in the core areas of classical mechanics, electricity and magnetism, quantum mechanics, and statistical and thermal physics are required. It is advisable to have taken an upper division course in experimental methods in physics.

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 55
- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).
Program Requirements
40 credits are required in the major.
0 credits are required outside the major.
24 thesis credits are required.

This program may be completed with a minor.

Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.30 is required for students to remain in good standing.

Physics 4001, 4002, 4101, 4201, and 4303 cannot be used to satisfy the requirements.

Students whose financial support comes from TA assignments are also required to complete 3 credits of PHYS 5072 over two semesters. These credits count towards elective requirements.

Required orientation: Before the beginning of fall semester, new graduate students are expected to participate in the department orientation program. This includes TA orientation sessions, which are required if a student's financial support comes from TA assignments.

Requirement for international students: International students who want to teach as TAs must take CSE TALK, a workshop on American teaching culture and language skills, prior to the department orientation described above and achieve an ELP (English Language Proficiency) rating of 1. This includes passing an English test, which is given in late July and August. Students who do not achieve an ELP of 1 must take an English training course geared to their level of skills, such as GRAD 5105, GRAD 5102, or Foundations. These courses are given during the academic year and are required until the student achieves an ELP of 1.

Required Courses
- PHYS 5001 - Quantum Mechanics I (4.0 cr)
- PHYS 5002 - Quantum Mechanics II (4.0 cr)
- PHYS 5011 - Classical Physics I (4.0 cr)
- PHYS 5012 - Classical Physics II (4.0 cr)
- PHYS 5201 - Thermal and Statistical Physics (3.0 cr)

Seminars
Take 2 or more course(s) totaling 2 or more credit(s) from the following:
- PHYS 8100 - Seminar: Problems of Physics Teaching and Higher Education (1.0 cr)
- PHYS 8200 - Seminar: Cosmology and High Energy Astrophysics (1.0 cr)
- PHYS 8300 - Seminar: Biological and Medical Physics. (1.0 cr)
- PHYS 8600 - Seminar: Space Physics (1.0 cr)
- PHYS 8700 - Seminar: Condensed Matter Physics (1.0 cr)
- PHYS 8800 - Seminar: Nuclear Physics (1.0 cr)
- PHYS 8900 - Seminar: Elementary Particle Physics (1.0 cr)

Electives
Students may choose courses from this list or consult with their advisor for additional options.
Take 19 or more credit(s) from the following:

Atomic Physics and Optics
- PHYS 8161 - Atomic and Molecular Structure (3.0 cr)

Biophysics and Medical Physics
- PHYS 5081 - Introduction to Biopolymer Physics (3.0 cr)
- PHYS 5401 - Physiological Physics (4.0 cr)
- PHYS 5402 - Radiological Physics (4.0 cr)
- PHYS 8311 - Biological Physics of Single Molecules (3.0 cr)
- PHYS 8312 - Biological Physics of Macroscopic Systems (3.0 cr)
- PHYS 8300 - Seminar: Biological and Medical Physics. (1.0 cr)

Condensed Matter Physics
- PHYS 4211 - Introduction to Solid-State Physics (3.0 cr)
- PHYS 5701 - Solid-State Physics for Engineers and Scientists (4.0 cr)
- PHYS 8702 - Statistical Mechanics and Transport Theory (3.0 cr)
- PHYS 8711 - Solid-State Physics I (3.0 cr)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 8712</td>
<td>Solid-State Physics II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8750</td>
<td>Advanced Topics in Condensed Matter Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8700</td>
<td>Seminar: Condensed Matter Physics</td>
<td>1.0 cr</td>
</tr>
<tr>
<td><strong>Elementary Particle Physics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 4511</td>
<td>Introduction to Nuclear and Particle Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8011</td>
<td>Quantum Field Theory I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8012</td>
<td>Quantum Field Theory II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8013</td>
<td>Special Topics in Quantum Field Theory</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8901</td>
<td>Elementary Particle Physics I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8902</td>
<td>Elementary Particle Physics II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8911</td>
<td>Introduction to Supersymmetry</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8950</td>
<td>Advanced Topics in Elementary Particle Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8900</td>
<td>Seminar: Elementary Particle Physics</td>
<td>1.0 cr</td>
</tr>
<tr>
<td><strong>Mathematical, Advanced Quantum, and Computational Physics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 5041</td>
<td>Mathematical Methods for Physics</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 8001</td>
<td>Advanced Quantum Mechanics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8301</td>
<td>Symmetry and Its Application to Physical Problems</td>
<td>3.0 cr</td>
</tr>
<tr>
<td><strong>Nuclear Physics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 8801</td>
<td>Nuclear Physics I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8802</td>
<td>Nuclear Physics II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8850</td>
<td>Advanced Topics in Nuclear Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8800</td>
<td>Seminar: Nuclear Physics</td>
<td>1.0 cr</td>
</tr>
<tr>
<td><strong>Plasma and Space Physics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 4611</td>
<td>Introduction to Space Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 4621</td>
<td>Introduction to Plasma Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8601</td>
<td>Plasma Physics I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8602</td>
<td>Plasma Physics II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8611</td>
<td>Cosmic Rays and Plasma Astrophysics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8650</td>
<td>Advanced Topics in Space and Plasma Physics</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8600</td>
<td>Seminar: Space Physics</td>
<td>1.0 cr</td>
</tr>
<tr>
<td><strong>Relativity and Cosmology</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 5022</td>
<td>Relativity, Cosmology, and the Universe</td>
<td>4.0 cr</td>
</tr>
<tr>
<td>PHYS 8501</td>
<td>General Relativity and Cosmology I</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8502</td>
<td>General Relativity and Cosmology II</td>
<td>3.0 cr</td>
</tr>
<tr>
<td>PHYS 8200</td>
<td>Seminar: Cosmology and High Energy Astrophysics</td>
<td>1.0 cr</td>
</tr>
<tr>
<td><strong>Physics Education</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 5072</td>
<td>Best Practices in College Physics Teaching</td>
<td>1.0 - 3.0 cr</td>
</tr>
<tr>
<td>PHYS 8100</td>
<td>Seminar: Problems of Physics Teaching and Higher Education</td>
<td>1.0 cr</td>
</tr>
</tbody>
</table>

**Thesis Credits**
Take 24 credits (maximum 14 credits per term) after passing preliminary oral exam.

PHYS 8888 - Thesis Credit: Doctoral (1.0 - 24.0 cr)
Twin Cities Campus
Quaternary Paleoecology Minor
Department of Earth Sciences
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Quaternary Paleoecology Graduate Program, University of Minnesota, John T. Tate Hall-Suite 150, 116 Church St. SE, Minneapolis, MN 55455 (612-624-7881; fax: 612-625-3819)
Email: qpminor@umn.edu
Website: http://lrc.geo.umn.edu/qpminor/index.html

- Program Type: Graduate free-standing minor
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 6
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The faculty of the graduate minor in quaternary paleoecology (QP) hold appointments in several departments. Students in this unique program benefit from the broad range of expertise and experience available at a large research university. From their coursework in the minor, graduate students learn techniques and approaches from other areas that can be applied to their own research.

The minor is available to master's (MA and MS) and doctoral students.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
Other requirements to be completed before admission:
Students must be enrolled in a graduate program (master's or doctoral) at the University of Minnesota.

Special Application Requirements:
Students apply by sending a letter of application to the director of graduate studies (qpminor@umn.edu) as well as a letter of endorsement from their major adviser. Application may be made at any time.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

The Quaternary Paleoecology minor curriculum is developed in consultation with the major advisor and the Quaternary Paleoecology director of graduate studies. Courses must be from relevant disciplines outside the major field.

Minor Courses
Masters students select at least 6 credits, and doctoral students select at least 12 credits from the following list. Alternative coursework can be applied to the minor with approval from the major advisor and Quaternary Paleoecology director of graduate studies.

ANTH 4077 - Neanderthals: Biology and Culture of Humanity's Nearest Relative (3.0 cr)
ANTH 4329 - Primate Ecology and Social Behavior (3.0 cr)
ANTH 5009 - Human Behavioral Biology (3.0 cr)
ANTH 5269 - Analysis of Stone Tool Technology (4.0 cr)

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
ANTH 5401 - The Human Fossil Record (3.0 cr)
ANTH 5402 - Zooarchaeology Laboratory (3.0 cr)
ANTH 5403 - Quantitative Methods in Biological Anthropology (4.0 cr)
ANTH 5405 - Human Skeletal Analysis (4.0 cr)
ANTH 5442 - Archaeology of the British Isles (3.0 cr)
CEGE 5541 - Environmental Water Chemistry (3.0 cr)
CEGE 8511 - Mechanics of Sediment Transport (3.0 cr)
CEGE 8522 - Biometeorology (3.0 cr)
CEGE 8551 - Environmental Microbiology; Molecular Theory and Methods (4.0 cr)
CEGE 8552 - Groundwater Microbiology; Laboratory (4.0 cr)
CEGE 8553 - Biofilms (3.0 cr)
CEGE 8561 - Analysis and Modeling of Aquatic Environments I (3.0 cr)
CEGE 8562 - Analysis and Modeling of Aquatic Environments II (3.0 cr)
CEGE 8581 - Research and Professional Ethics in Water Resources and Environmental Science (0.5 cr)
CEGE 8601 - Introduction to Stream Restoration (3.0 cr)
CEGE 8602 - Stream Restoration Practice (2.0 cr)
EEB 4329 - Primate Ecology and Social Behavior (3.0 cr)
EEB 4611 - Biogeochemical Processes (3.0 cr)
EEB 5221 - Molecular Evolution (3.0 cr)
EEB 5371 - Principles of Systematics (3.0 cr)
EEB 5601 - Limnology (3.0 cr)
EEB 5605 - Limnology Laboratory (2.0 cr)
EEB 5609 - Ecosystem Ecology (3.0 cr)
ESCI 4102W - Vertebrate Paleontology: Evolutionary History and Fossil Records of Vertebrates [WI] (3.0 cr)
ESCI 4103W - Fossil Record of Mammals [WI] (3.0 cr)
ESCI 4401 - Aqueous Environmental Geochemistry (3.0 cr)
ESCI 4402 - Biogeochemical Cycles in the Ocean (3.0 cr)
ESCI 4602 - Sedimentology and Stratigraphy (3.0 cr)
ESCI 4703 - Glacial Geology (4.0 cr)
ESCI 5102 - Climate Change and Human History (3.0 cr)
ESCI 5201 - Time-Series Analysis of Geological Phenomena (3.0 cr)
ESCI 5204 - Geostatistics and Inverse Theory (3.0 cr)
ESCI 5302 - Isotope Geology (3.0 cr)
ESCI 5601W - Advanced Sedimentology [WI] (4.0 cr)
ESCI 5705 - Limnogeology and Paleoenvironment (3.0 cr)
ESCI 8243 - Principles of Rock Magnetism (1.0 - 3.0 cr)
ESCI 8511 - Mechanics of Sediment Transport (3.0 cr)
ESPM 5402 - Biometeorology (3.0 cr)
FNRM 5131 - Geographical Information Systems (GIS) for Natural Resources (4.0 cr)
FNRM 5153 - Forest Hydrology & Watershed Biogeochemistry (3.0 cr)
FNRM 5203 - Forest Fire and Disturbance Ecology (3.0 cr)
FNRM 5204 - Landscape Ecology and Management (3.0 cr)
FNRM 5205 - Productivity and Ecology of Forest Soils (3.0 cr)
FNRM 5218 - Measuring and Modeling Forests (3.0 cr)
FNRM 5262 - Remote Sensing and Geospatial Analysis of Natural Resources and Environment (3.0 cr)
FNRM 5412 - Advanced Remote Sensing and Geospatial Analysis (3.0 cr)
GEOG 5401 - Geography of Environmental Systems and Global Change (4.0 cr)
GEOG 5426 - Climatic Variations (3.0 cr)
GEOG 5431 - Plant and Animal Geography (3.0 cr)
GEOG 5531 - Numerical Spatial Analysis (4.0 cr)
GEOG 5561 - Principles of Geographic Information Science (4.0 cr)
GEOG 5839 - Introduction to Dendrochronology (3.0 cr)
LAAS 5050 - Integrated Topics in Land & Atmospheric Science (3.0 cr)
LAAS 5425 - Atmospheric Processes I: Thermodynamics and Dynamics of the Atmosphere (3.0 cr)
LAAS 5426 - Atmospheric Processes II: Radiation, Composition, and Climate (3.0 cr)
SOIL 4511 - Field Study of Soils (2.0 cr)
SOIL 5555 - Wetland Soils (3.0 cr)
SOIL 8510 - Advanced Topics in Pedology (2.0 - 4.0 cr)
SOIL 8541 - Aquatic and Soil Chemistry (3.0 cr)

Program Sub-plans

Students are required to complete one of the following sub-plans.
Students may not complete the program with more than one sub-plan.

Masters

Doctoral
Twin Cities Campus
Security Technologies M.S.S.T.
Technological Leadership Institute
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Security Technologies Graduate Program, Technological Leadership Institute, University of Minnesota, 290 McNamara Alumni Center, 200 Oak Street SE, Minneapolis MN 55455 (612-624-5474; fax: 612-624-7510)
Email: tliss@umn.edu
Website: http://tli.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 32
- This program requires summer semesters for timely completion.
- Degree: Master of Science in Security Technologies

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The master of science in security technologies (MSST) shapes tomorrow's analytical and risk management policy makers and innovators through a multi-disciplinary graduate program developed in response to growing demand in many levels of industry and government. During the 14-month program and through a multidisciplinary systems approach, the program synthesizes core learning in four areas: security methods and foundations; application expertise (including cyber, bio, food, infrastructure, global supply chains); systems science (interdependency among critical networks, components, human capital, organizational dimensions); and social and policy dimensions. Through elective courses, students also choose a learning track in either security systems technologies or security risk management. Students can further specialize through a range of elective courses. This program bridges disciplines to address local, regional, national, and global areas of need, seeding innovative capabilities while enabling interdisciplinary connections through direct links to industry, business, and government partners.

Program Delivery
This program is available:
• via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A bachelor's degree in a related field, e.g. in biological or physical sciences, engineering, computer science, mathematics, statistics, social sciences, or public policy.

Other requirements to be completed before admission:
Applicants should have one year of calculus, probability/statistics, or two science or engineering courses.

Special Application Requirements:
Applications are accepted on a rolling basis for the program's start in the summer of each year. Additional information is available at msst.umn.edu.

International applicants must submit score(s) from one of the following tests:
• TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
• IELTS
  - Total Score: 6.5
• MELAB
  - Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).
For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

**Plan B:** Plan B requires 26 major credits and 6 credits outside the major. The final exam is written and oral. A capstone project is required.

**Capstone Project:** The Plan B project is an independent applied investigation on a relevant issue in security technologies or homeland security.

This program may be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 3.25 is required for students to remain in good standing.

The MSST program requires 32 credits in the fields of systems risk analysis, engineering (hardware and software), emerging technologies, economics, human factors, law, food and bio safety, and public policy to teach and investigate security technologies and address pertinent issues. The 32 credits consist of 24 credits in MSST core courses, 2 credits for the capstone course, and 6 credits in electives outside the major.

**Core Courses**
Take 0.5 credits of ST 8440

ST 8109 - Cybersecurity Foundations - Technology, Risk & Communication (2.0 cr)
ST 8110 - Security Science and Technology Foundations (3.0 cr)
ST 8111 - Methods, Theory, and Applications (2.5 cr)
ST 8113 - Information and Cyber Security (2.0 cr)
ST 8220 - Vulnerability, Risk and Threat Assessment and Management (3.0 cr)
ST 8221 - Communications of Risk and Security (1.0 cr)
ST 8330 - Critical Infrastructure Protections (3.0 cr)
ST 8331 - Dynamic Systems Modeling and Simulation Tools (2.0 cr)
ST 8440 - Security Practicum (0.5 - 2.0 cr)
ST 8510 - Psychology/Behavior Intelligence for Homeland Security (2.0 cr)
ST 8511 - Public Policy (1.0 cr)
ST 8512 - Partnership in Conflict Management: Security/Privacy Law, Social Responsibility and Ethics (2.0 cr)

**Capstone Project**
Take a total of 2 credits

ST 8620 - Capstone (0.5 - 2.0 cr)

**Electives**
Other courses may be selected in consultation with the director of graduate studies.

Take 6 or more credit(s) from the following:

- CI 5301 - Foundations of Computer Applications for Business and Education (3.0 cr)
- CSCI 5221 - Foundations of Advanced Networking (3.0 cr)
- CSCI 5271 - Introduction to Computer Security (3.0 cr)
- CSCI 5471 - Modern Cryptography (3.0 cr)
- CSCI 8715 - Spatial Data Science Research (3.0 cr)
- ESPM 5604 - Environmental Management Systems and Strategy (3.0 cr)
- FNRM 5131 - Geographical Information Systems (GIS) for Natural Resources (4.0 cr)
- GEOG 5561 - Principles of Geographic Information Science (4.0 cr)
- GEOG 5563 - Advanced Geographic Information Science (3.0 cr)
- GEOG 5564 - Urban Geographic Information Science and Analysis (3.0 cr)
- GIS 5574 - Web GIS and Services (3.0 cr)
- GIS 5577 - Spatial Database Design and Administration (3.0 cr)
- IDSC 6040 - Information Technology Management (2.0 cr)
- IDSC 6050 - Information Technologies and Solutions (2.0 cr)
- IDSC 6423 - Enterprise Systems (2.0 cr)
- IDSC 6444 - Business Analytics for Managers I (2.0 cr)
- IDSC 6481 - Managerial Decision Making (2.0 cr)
- IDSC 8003 - Accounting and Information Systems (4.0 cr)
- LAW 6022 - LL.M. Legal Writing and Legal Skills II (3.0 cr)

© 2005 by the Regents of the University of Minnesota
The University of Minnesota is an equal opportunity educator and employer.
Information current as of August 31, 2018
- LAW 6103 - Data Privacy Law (3.0 cr)
- LAW 6705 - Information Governance (2.0 cr)
- LAW 6832 - Cybercrime and Cybersecurity (2.0 cr)
- MATH 5248 - Cryptology and Number Theory (4.0 cr)
- MATH 5251 - Error-Correcting Codes, Finite Fields, Algebraic Curves (4.0 cr)
- MGMT 6004 - Negotiation Strategies (2.0 cr)
- MGMT 6034 - Strategic Leadership (2.0 cr)
- MGMT 6084 - Management of Groups (2.0 cr)
- MGMT 6402 - Integrative Leadership: From Theory to Practice (3.0 cr)
- OLPD 5611 - Facilitation and Meeting Skills (1.0 cr)
- OLPD 5619 - Planning and Decision-Making Skills (1.0 cr)
- OLPD 6402 - Integrative Leadership Seminar (3.0 cr)
- PA 5011 - Management of Organizations (3.0 cr)
- PA 5105 - Integrative Leadership Seminar (3.0 cr)
- PA 5405 - Public Policy Implementation (3.0 cr)
- PA 5701 - Science and State (3.0 cr)
- PA 5711 - Science, Technology & Environmental Policy (3.0 cr)
- PA 5741 - Risk, Resilience and Decision Making (1.5 cr)
- PA 5822 - International Security (3.0 cr)
- PA 8201 - Environment and Infrastructure Planning (4.0 cr)
- PA 8821 - National Security Policy (3.0 cr)
- POL 5885 - International Conflict and Security (3.0 cr)
- POL 8402 - International Security (3.0 cr)
- PUBH 5231 - Emergency Preparedness: A Public Health Perspective (2.0 cr)
- PUBH 6112 - Environmental Health Risk Assessment: Application to Human Health Risks from Exposure to Chemicals (2.0 cr)
- PUBH 6123 - Violence Prevention and Control: Theory, Research, and Application (2.0 cr)
- PUBH 6182 - Emerging Infectious Disease: Current Issues, Policies, and Controversies (3.0 cr)
- PUBH 6571 - Leading Performance Improvement in Health Care (2.0 cr)
- PUBH 6702 - Integrative Leadership Seminar (3.0 cr)
- PUBH 7214 - Principles of Risk Communication (1.0 cr)
- PUBH 7221 - Planning for Urgent Threats (1.0 cr)
- PUBH 7223 - Concepts of Disaster Behavioral Health (1.0 cr)
- PUBH 7225 - Communication and Information Technology Tools for Public Health Emergency Response (1.0 cr)
- PUBH 7227 - Incident Management Systems: The Public Health Role (1.0 cr)
- PUBH 7230 - Topics in Infectious Disease (0.5 - 4.0 cr)
- PUBH 7233 - Food System Defense: Vulnerabilities in the Food System (1.5 cr)
- PUBH 7242 - War and Public Health (1.0 cr)
- SCO 6059 - Quality Management and Lean Six Sigma (4.0 cr)
- SCO 8892 - Social Network Analysis: Theory and Methods (3.0 cr)
- ST 8200 - Special Topics in Security Technologies (0.5 cr)
- ST 8441 - Internship (optional) (0.5 cr)
- VMED 5920 - Food Defense: Prepare, Respond, Recover (3.0 cr)
- WRIT 5001 - Introduction to Graduate Studies in Scientific and Technical Communication (3.0 cr)
- WRIT 5112 - Information Design: Theory and Practice (3.0 cr)
- WRIT 5561 - Editing and Style for Technical Communicators (3.0 cr)

**Special Topics Electives**

The following electives are topics courses. Only the approved topic titles below may be used.

- CSCI 5980 - Computation Geo-Informatics (3 credits)
- HIST 5900 - European Nationalism and National Identity (3 credits)
- IDSC 6490 - Information-Based Goods in the Network Economy (2 credits)
- PA 5190 - Managing Conflict: Negotiation (3 credits)
- PA 5890 - International Crisis Simulation (1 credit)
- PA 5920 - Action-Oriented Strategy Mapping (1 credit)
- PA 5920 - Assessing Leadership Capability (1 credit)
- PA 7120 - Stakeholder/STOW Analysis and Casual Mapping (0.5 credits)
- PA 8790 - Risk Analysis for Science and Technology Policy (3 credits)
- PUBH 7200 - Best Practices in Emergency Response (1 credit)
- PUBH 7220 - Data Driven Decision-Making (1 credit)
- PUBH 7220 - Design for Disaster (1 credit)
- PUBH 7220 - Disaster 101 (1 credit)
- PUBH 7220 - Epidemiology of Foodborne Pathogens (1 credit)
- PUBH 7220 - Farm to Table Study Program (2 credits)
- PUBH 7220 - Food Defense: Vulnerabilities in Food System and How to Close Them (1 credit)
- PUBH 7220 - Food Facility Bio-Security: Cleaning and Sanitation for Food Facilities (1 credit)
Twin Cities Campus
Security Technologies Minor
Technological Leadership Institute
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Security Technologies Graduate Program, Technological Leadership Institute, University of Minnesota, 290 McNamara Alumni Center, 200 Oak Street SE, Minneapolis MN 55455 (612-624-5474; fax: 612-624-7510)
Email: tliss@umn.edu
Website: http://tli.umn.edu

- Program Type: Graduate minor related to major
- Requirements for this program are current for Fall 2018
- Length of program in credits (Masters): 7
- Length of program in credits (Doctorate): 12
- This program does not require summer semesters for timely completion.

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The security technologies graduate program shapes tomorrow's analytical and risk management policy makers and innovators through a multi-disciplinary graduate program developed in response to growing demand in many levels of industry and government. Through a multidisciplinary systems approach, the program synthesizes core learning in four areas: security methods and foundations; application expertise (including cyber, bio, food, infrastructure, global supply chains); systems science (interdependency among critical networks, components, human capital, organizational dimensions); and social and policy dimensions. Through elective courses, students choose a learning track in either security systems technologies or security risk management. Students can further specialize through a range of elective courses. This program bridges disciplines to address local, regional, national, and global areas of need, seeding innovative capabilities while enabling interdisciplinary connections through direct links to industry, business, and government partners.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

Special Application Requirements:
Applicants for the minor must be enrolled in a degree program at the University of Minnesota and must be interviewed for admission (in person or by telephone) by the DGS or designate, except in rare circumstances where this requirement may be waived.

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements
Use of 4xxx courses towards program requirements is not permitted.

Program Sub-plans
Students are required to complete one of the following sub-plans. Students may not complete the program with more than one sub-plan.

Masters
Minor Courses
- Take 7 or more credit(s) from the following:
  - ST 8109 - Cybersecurity Foundations - Technology, Risk & Communication (2.0 cr)
  - ST 8110 - Security Science and Technology Foundations (3.0 cr)
• ST 8111 - Methods, Theory, and Applications (2.5 cr)
• ST 8113 - Information and Cyber Security (2.0 cr)
• ST 8200 - Special Topics in Security Technologies (0.5 cr)
• ST 8220 - Vulnerability, Risk and Threat Assessment and Management (3.0 cr)
• ST 8221 - Communications of Risk and Security (1.0 cr)
• ST 8330 - Critical Infrastructure Protections (3.0 cr)
• ST 8331 - Dynamic Systems Modeling and Simulation Tools (2.0 cr)
• ST 8440 - Security Practicum (0.5 - 2.0 cr)
• ST 8510 - Psychology/Behavior Intelligence for Homeland Security (2.0 cr)
• ST 8511 - Public Policy (1.0 cr)
• ST 8512 - Partnership in Conflict Management: Security/Privacy Law, Social Responsibility and Ethics (2.0 cr)
• ST 8661 - Securing Cyberspace (Fundamentals) (3.0 cr)

Doctoral

Minor Courses
Take 12 or more credit(s) from the following:
• ST 8109 - Cybersecurity Foundations - Technology, Risk & Communication (2.0 cr)
• ST 8110 - Security Science and Technology Foundations (3.0 cr)
• ST 8111 - Methods, Theory, and Applications (2.5 cr)
• ST 8113 - Information and Cyber Security (2.0 cr)
• ST 8200 - Special Topics in Security Technologies (0.5 cr)
• ST 8220 - Vulnerability, Risk and Threat Assessment and Management (3.0 cr)
• ST 8221 - Communications of Risk and Security (1.0 cr)
• ST 8330 - Critical Infrastructure Protections (3.0 cr)
• ST 8331 - Dynamic Systems Modeling and Simulation Tools (2.0 cr)
• ST 8440 - Security Practicum (0.5 - 2.0 cr)
• ST 8510 - Psychology/Behavior Intelligence for Homeland Security (2.0 cr)
• ST 8511 - Public Policy (1.0 cr)
• ST 8512 - Partnership in Conflict Management: Security/Privacy Law, Social Responsibility and Ethics (2.0 cr)
• ST 8661 - Securing Cyberspace (Fundamentals) (3.0 cr)
Twin Cities Campus
Software Engineering M.S.S.E.
Computer Science and Engineering
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
MSSE Program, Department of Computer Science and Engineering, College of Science and Engineering, 4-192 Keller Hall, 200 Union Street S.E., Minneapolis, MN 55455 (612-625-1381; msse@umn.edu)
Email: msse@cs.umn.edu
Website: http://www.msse.umn.edu

- Program Type: Master's
- Requirements for this program are current for Fall 2018
- Length of program in credits: 30
- This program does not require summer semesters for timely completion.
- Degree: Master of Science in Software Engineering

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The Master of Science in Software Engineering (MSSE) program provides a thorough understanding of the fundamental issues related to software development and the software development process. The MSSE curriculum provides a solid grounding in theoretical methods, principles, and tools, and an examination of fundamental software development issues and processes. These concepts are explored using realistic and relevant case examples and projects to ensure that the theory works in practice. The MSSE program is an interdisciplinary program administered by the College of Science and Engineering's Department of Computer Science and Engineering.

The program is offered in a format designed for full-time working professionals. Students take courses one day per week (alternating Fridays and Saturdays) and move through the curriculum as a cohort, taking all classes together for four semesters.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

Prospective students should have an undergraduate degree in computer science or a closely related field.

Other requirements to be completed before admission:
Students with degrees in other fields may be considered for admission based on relevant work experience.
Prospective applicants must have a minimum of one year of professional experience working in the software industry.
Because the MSSE program is designed for full-time working professionals, international applicants typically hold an H-1B visa.

Special Application Requirements:
The early application deadline is March 31. The final deadline is July 1. Applications are accepted for fall semester only. Additional information is available at http://www.msse.umn.edu/how-to-apply

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
- IELTS
- Total Score: 6.5
- MELAB
- Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.

Program Requirements

**Plan C:** Plan C requires 30 major credits and up to null credits outside the major. There is no final exam.

This program may not be completed with a minor.

Use of 4xxx courses towards program requirements is not permitted.

A minimum GPA of 3.00 is required for students to remain in good standing.

The MSSE requires 30 credits. The curriculum is fixed for the first three semesters. The fourth semester offers electives, including an optional independent project. Students take eight core courses, two industrial seminar courses, and 2 elective courses. The project requirement can be met by a combination of class projects or by an independent project elective.

**Core Courses**

- SENG 5115 - Graphical User Interface Design, Evaluation, and Implementation (2.0 cr)
- SENG 5707 - The Principles of Database Systems (3.0 cr)
- SENG 5801 - Software Engineering I: Overview, Requirements, and Modeling (3.0 cr)
- SENG 5802 - Software Engineering II: Software Design (3.0 cr)
- SENG 5811 - Software Testing and Verification (2.0 cr)
- SENG 5851 - Software Project Management (3.0 cr)
- SENG 5852 - Quality Assurance and Process Improvement (3.0 cr)
- SENG 5861 - Introduction to Software Architecture (3.0 cr)

**Industrial Seminar**

Take twice for a total of 2 credits
- SENG 5899 - Software Engineering Seminar (1.0 cr)

**Electives**

Choose a minimum of 6 credits in SENG electives in consultation with adviser
Twin Cities Campus
Stream Restoration Science and Engineering Postbaccalaureate Certificate
CSENG Civil, Envrn & Geo-Eng (CEGE)
College of Science and Engineering

Link to a list of faculty for this program.

Contact Information:
Stream Restoration Graduate Certificate Program, National Center for Earth-surface Dynamics, Saint Anthony Falls Laboratory, 2 Third Avenue SE, Minneapolis, MN 55414 (612-624-4363)
Email: volle001@umn.edu
Website: http://www.nced.umn.edu/apply-certificate-program-stream-restoration

- Program Type: Post-baccalaureate credit certificate/licensure/endorsement
- Requirements for this program are current for Fall 2018
- Length of program in credits: 16
- This program does not require summer semesters for timely completion.
- Degree: Stream Rest. Science & Engineering PBacc Cert

Along with the program-specific requirements listed below, please read the General Information section of the catalog website for requirements that apply to all major fields.

The postbaccalaureate certificate in stream restoration science and engineering is a three-semester program producing graduates who understand how to blend engineering, physical, biological, and social sciences in prioritizing, designing, implementing, and evaluating stream restoration projects. Two courses, including an introduction to stream restoration and a restoration design experience are required. The remaining courses are chosen from a specified list of relevant courses taught across a number of University departments.

Program Delivery
This program is available:
- via classroom (the majority of instruction is face-to-face)

Prerequisites for Admission
The preferred undergraduate GPA for admittance to the program is 3.00.

A bachelor's degree in a field related to ecology, civil engineering, or environmental and earth sciences from an accredited US institution or its foreign equivalent.

Other requirements to be completed before admission:
In addition to the University's online application form, students must submit a program application and one letter of reference. The SRSE program application form and directions for submission can be found at nced.umn.edu/apply-certificate-program-stream-restoration.

Applications are accepted throughout the year.

International applicants must submit score(s) from one of the following tests:
- TOEFL
  - Internet Based - Total Score: 79
  - Internet Based - Writing Score: 21
  - Internet Based - Reading Score: 19
  - Paper Based - Total Score: 550
- IELTS
  - Total Score: 6.5
- MELAB
  - Final score: 80

Key to test abbreviations (TOEFL, IELTS, MELAB).

For an online application or for more information about graduate education admissions, see the General Information section of the catalog website.
Program Requirements
Use of 4xxx courses toward program requirements is permitted under certain conditions with adviser approval.

A minimum GPA of 3.00 is required for students to remain in good standing.

Required Coursework
Foundation Course
The foundation course is also offered as EEB/ESCI 8601. Students pursuing a degree in earth sciences, civil engineering, or ecology, evolution and behavior should register for the foundation course under a designator other than that of their major.

CEGE 8601 - Introduction to Stream Restoration (3.0 cr)

Elective Coursework
Take 11 or more credit(s) from the following:

River and Floodplain Science and Engineering
Take 1 or more course(s) from the following:

• BBE 5513 - Watershed Engineering (3.0 cr)
• BBE 8513 - Hydrologic Modeling of Small Watersheds (3.0 cr)
• CEGE 4511 - Hydraulic Structures (3.0 cr)
• CEGE 4512 - Open Channel Hydraulics (4.0 cr)
• CEGE 4501 - Hydrologic Design (4.0 cr)
• CEGE 8511 - Mechanics of Sediment Transport (3.0 cr)
• FNRM 5114 - Hydrology and Watershed Management (3.0 cr)
• FNRM 5153 - Forest Hydrology & Watershed Biogeochemistry (3.0 cr)
• ESCI 4701 - Geomorphology (4.0 cr)

River and Floodplain Ecology
• CEGE 8508 - Ecological Fluid Mechanics (4.0 cr)
• EEB 5601 - Limnology (3.0 cr)
• FW 8465 - Fish Habitats and Restoration (3.0 cr)
• FW 8459 - Stream and River Ecology (3.0 cr)
• HORT 5071 - Ecological Restoration (4.0 cr)

Water Quality
• CEGE 5541 - Environmental Water Chemistry (3.0 cr)
• CEGE 8541 - Aquatic Chemistry (3.0 cr)
• CEGE 8561 - Analysis and Modeling of Aquatic Environments I (3.0 cr)
• CEGE 8562 - Analysis and Modeling of Aquatic Environments II (3.0 cr)
• ESCI 4702 - General Hydrogeology (4.0 cr)
• ESPM 5111 - Hydrology and Water Quality Field Methods (3.0 cr)

Water Policy and Management
Take at most 4 credit(s) from the following:

• ESPM 4295W - GIS in Environmental Science and Management [WI] (4.0 cr)
• ESPM 5061 - Water Quality and Natural Resources (3.0 cr)
• ESPM 5202 - Environmental Conflict Management, Leadership, and Planning (3.0 cr)
• ESPM 5703 - Agroforestry in Watershed Management (3.0 cr)
• WRS 5101 - Water Policy (3.0 cr)

Capstone Course
The capstone course is also offered as EEB/ESCI 8602. Students pursuing a degree in earth sciences, civil engineering, or ecology, evolution and behavior should register for the capstone course under a designator other than that of their major.

CEGE 8602 - Stream Restoration Practice (2.0 cr)