Robotics

Degrees Offered

• Graduate Certificate in Robotics
• Master of Science in Robotics (Non-Thesis)
• Master of Science in Robotics (Thesis)
• Doctor of Philosophy in Robotics

The Robotics program offers the degrees of Master of Science and Doctor of Philosophy in Robotics. The non-thesis MS is designed to prepare candidates for industry careers in robotics. The thesis MS and PhD degrees are designed to prepare students for research careers. The graduate certificate is intended for working professionals.

Combined Program: The Robotics program also offers combined BS+MS degrees. These degrees offer an expedited graduate school application process and allow students to begin graduate coursework while still finishing their undergraduate degree requirements.

Admission

Mines’ Combined Undergraduate / Graduate Degree Program

Current Mines undergraduate students are encouraged to apply for the combined program once they have taken five or more technical classes at Mines (classes transferred from other universities will not be considered). This requirement may be met by any 200-level or above course with a CSCI, MEGN, or EENG prefix, excluding field session and senior design courses.

Students enrolled in Mines’ Combined Undergraduate/Graduate Program (meaning uninterrupted registration from the time the student earns a Mines undergraduate degree to the time the student begins a Mines graduate degree) may double count up to six hours of credits which were used in fulfilling the requirements of their undergraduate degree at Mines, towards their graduate program. Any courses that count towards the graduate degree requirements as either “Required Coursework” or “Elective Coursework”, as defined below, may be used for the purposes of double counting at the discretion of the advisor (MS Non-Thesis) or thesis committee (MS Thesis or PhD). These courses must have been passed with a “B-” or better and meet all other University, Department, Division, and Program requirements for graduate credit.

MS and PhD

The minimum requirements for admission to the MS and PhD degrees in Robotics are:

• Applicants must have a Bachelor’s degree, or equivalent, from an accredited institution with a grade-point average of 3.0 or better on a 4.0 scale prior to matriculating into the Robotics degree program.

• Students are expected to have completed the following coursework: (1) two semesters of calculus, (2) differential equations, and (3) data structures. The Robotics graduate admissions committee may require that students who do not meet this expectation demonstrate competency or take remedial coursework. Such coursework may not count toward the graduate degree. The committee will decide whether to recommend regular or provisional admission.

• Graduate Record Examination (Quantitative section) score of 151 or higher (or 650 on the old scale). Applicants who have graduated with a computer science, engineering, or math degree from Mines within the past five years are not required to submit GRE scores.

• TOEFL score of 79 or higher (or 550 for the paper-based test or 213 for the computer- based test) for applicants whose native language is not English. In lieu of a TOEFL score, and IELTS score of 6.5 or higher will be accepted.

• For the PhD program, prior research experience is desired but not required.

Transfer Credit

Graduate level courses taken at other universities for which a grade equivalent to a “B” or better was received will be considered for transfer credit with approval of the Advisor and/or Thesis Committee, and home department head, as appropriate. Transfer credits must not have been used as credit toward a Bachelor degree. For the MS degree, no more than nine credits may transfer. For the PhD degree, up to 24 credit hours of courses may be transferred. In lieu of transfer credit for individual courses, students who enter the PhD program with a thesis-based master’s degree from another institution may transfer up to 36 hours in recognition of the course work and research completed for that degree.

400-level Courses

As stipulated by the Mines Graduate School, students may apply toward graduate degree requirements a maximum of nine (9.0) semester hours of department- approved 400-level course work.

Advisor and Thesis Committee

Students must have an Advisor from the Robotics faculty to direct and monitor their academic plan, research, and independent studies. Advisors must be full-time permanent members of the faculty. In this context, full-time permanent members of the faculty are those that hold the rank of professor, associate professor, assistant professor, research professor, associate research professor or assistant research professor. Upon approval by the Graduate Dean, adjunct faculty, teaching faculty, visiting professors, emeritus professors and off-campus representatives may be designated additional co-advisors. A list of Robotics faculty by rank is available in the faculty tab of the catalog.

The department of the Advisor is the student’s home department.

Master of Science (thesis option) students in Robotics must have at least three members on their Thesis Committee. In addition to the institutional requirements, at least one committee member who is not the advisor must be Robotics faculty.

Robotics PhD Thesis Committees must have at least four members. In addition to the institutional requirements, at least one committee member who is not the advisor must be Robotics faculty.

Program Requirements

Graduate Certificate

The graduate certificate will require 12 credit hours of coursework. Table 3 summarizes the requirements for the graduate certificate. Please note: only 3 of the 12 credit hours can include coursework at the 400-level or lower to achieve the Graduate Certificate.

Robotics Core Four courses, one from each focus area’s core course list 12.0

Total Semester Hrs 12.0

Table 3: Robotics Graduate Certificate Summary Requirements
MS Degrees

The MS degrees will require 30 credit hours, with thesis options substituting for electives.

**MS Non-Thesis (MS-NT)** Students must take 30 credit hours of coursework to complete the degree. Table 1 summarizes the requirements for the MS-NT degree.

<table>
<thead>
<tr>
<th>Robotics Core (Breadth)</th>
<th>Four courses, one from each focus area's core course list</th>
<th>12.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotics Electives (Depth)</td>
<td>Two courses from robotics course list</td>
<td>6.0</td>
</tr>
<tr>
<td>Technical Electives</td>
<td>Four courses in any participating robotics department (CSCI, EENG, MEGN)</td>
<td>12.0</td>
</tr>
<tr>
<td><strong>Total Semester Hrs</strong></td>
<td><strong>30.0</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Robotics MS Non-Thesis Summary Requirements

**MS Thesis** Students must take 21 credit hours of coursework and 9 credit hours of MS thesis research to complete the degree. Table 2 summarizes the requirements for the MS Thesis degree.

At the conclusion of the MS Thesis, the student must make a formal presentation and defense of their thesis research. A student must "pass" this defense to earn an MS degree.

<table>
<thead>
<tr>
<th>Robotics Core (Breadth)</th>
<th>Four courses, one from each focus area's core course list</th>
<th>12.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotics Electives (Depth)</td>
<td>Two courses from robotics course list</td>
<td>6.0</td>
</tr>
<tr>
<td>Technical Electives</td>
<td>One course in any participating robotics department (CSCI, EENG, MEGN)</td>
<td>3.0</td>
</tr>
<tr>
<td>MEGN707</td>
<td>GRADUATE THESIS / DISSERTATION RESEARCH CREDIT</td>
<td>9.0</td>
</tr>
<tr>
<td><strong>Total Semester Hrs</strong></td>
<td><strong>30.0</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Robotics MS Thesis Summary Requirements

**PhD Degree**

The Robotics PhD requires 36 credit hours of coursework, plus 36 research credit hours. Table 4 summarizes the coursework requirements and specific courses are listed below. PhD students must additionally complete a qualifying examination, a thesis proposal, and a thesis defense.

<table>
<thead>
<tr>
<th>Robotics Core (Breadth)</th>
<th>Four courses, one from each focus area's core course list</th>
<th>12.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotics Electives (Depth)</td>
<td>Four Courses from robotics course list</td>
<td>12.0</td>
</tr>
<tr>
<td>Technical Electives</td>
<td>Four courses in any participating robotics department (CSCI, EENG, MEGN)</td>
<td>12.0</td>
</tr>
<tr>
<td>MEGN707</td>
<td>GRADUATE THESIS / DISSERTATION RESEARCH CREDIT</td>
<td>36.0</td>
</tr>
<tr>
<td><strong>Total Semester Hrs</strong></td>
<td><strong>72.0</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Robotics PhD Summary Requirements

**Robotics PhD Qualifying Examination** The Robotics PhD Qualifying Examination will test a student's ability to conduct research in their chosen area. The qualifier will have two components: a coursework component and a research component.

- **Coursework Qualifier** To satisfy the coursework component of the qualifier, the student must complete their four selected robotics focus courses area with a minimum grade of "B" in each class.
- **Research Qualifier** The research qualifier consists of a research project. Robotics PhD students must take the qualifying examination by the end of their fourth semester (typically by the end of their second year). The examination will be evaluated by a committee consisting of at least the student’s advisor, a robotics-affiliated faculty (see section 5.1.2), and one additional faculty member.

For the qualifier, the student will conduct a literature review of 30-40 papers and perform a research project approaching the level necessary for a conference publication. The research project must be approved by the advisor and committee and will likely be some combination of the following:

- Design, analyze and/or simulate a novel robot system;
- Develop new algorithms or systems for an important research problem;
- Develop a new research software system;
- Solve a set of theoretical problems.

The deliverables will be a literature review (3-4 pages, IEEE style [4]), a research report (4-5 pages, IEEE style), and a research presentation (30 minutes to present, plus questions) delivered to the committee.

At the conclusion of the qualifier presentation, each committee member will vote their evaluation as one of “Strong Support”, “Weak Support”, or “Do not support.” The student must receive at least two “Strong Support” votes to pass. In the case the student does not pass, the committee may decide to offer a “conditional pass” based on extra conditions, such as revisions to the report or additional experiments, the student must perform to pass the qualifier. The committee will set an explicit deadline for student to complete the extra conditions. If the student does not meet the extra conditions as determined by the committee by the deadline, the “conditional pass” becomes a “fail.” If the student does not pass the qualifier on their first attempt (inclusive of a conditional pass), they may make one additional attempt to pass; the same conditional pass procedure may also be applied to the second attempt. A student who fails the qualifier on the second attempt may not continue in the program.

**Robotics PhD Proposal and Defense** After passing the qualifying examination, the student must prepare a written thesis proposal and present it formally to the student’s Thesis Committee and other interested faculty. Typically, the proposal will take place within 24 months of the student completing the qualifier.

The committee for the thesis proposal and defense will follow institutional requirements. Additionally, at least one committee member who is not the advisor must be robotics-affiliated faculty.

At the conclusion of the student’s PhD program, the student must make a formal presentation and defense of their thesis research. A student must
“pass” this defense to earn a PhD degree. Typically, the defense will take place within 24 months of the student completing the thesis proposal.

## Robotics Course List

### Perception

**Core Courses**
- **CSCI507** INTRODUCTION TO COMPUTER VISION 3.0
- **CSCI573** HUMAN-CENTERED ROBOTICS 3.0
- **EENG519** ESTIMATION THEORY AND KALMAN FILTERING 3.0

**Elective Courses**
- **CSCI508** ADVANCED TOPICS IN PERCEPTION AND COMPUTER VISION 3.0

### Cognition

**Core Courses**
- **CSCI404** ARTIFICIAL INTELLIGENCE 3.0
- **CSCI575** MACHINE LEARNING 3.0
- **CSCI534** ROBOT PLANNING AND MANIPULATION 3.0

**Elective Courses** - None.

### Action

**Core Courses**
- **MEGN540** MECHATRONICS 3.0
- **MEGN544** ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL 3.0
- **MEGN545** ADVANCED ROBOT CONTROL 3.0
- **EENG517** THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS 3.0

**Elective Courses**
- **EENG417** MODERN CONTROL DESIGN 3.0
- **EENG515** MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS 3.0

### Interaction & Society

**Core Courses**
- **CSCI5XX** HUMAN-ROBOT INTERACTION 3.0
- **CSCI532** ROBOT ETHICS 3.0

**Elective Courses**
- **CSCI5XX** LINGUISTIC HUMAN-ROBOT INTERACTION 3.0

### Additional Robotics Electives

- **CSCI406** ALGORITHMS 3.0
- **CSCI561** THEORY OF COMPUTATION 3.0
- **CSCI562** APPLIED ALGORITHMS AND DATA STRUCTURES 3.0
- **CSCI565** DISTRIBUTED COMPUTING SYSTEMS 3.0

**CSCI572** COMPUTER NETWORKS II 3.0
- **EENG411** DIGITAL SIGNAL PROCESSING 3.0
- **EENG511** CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS 3.0
- **EENG521** NUMERICAL OPTIMIZATION 3.0
- **MEGN586** LINEAR OPTIMIZATION 3.0
- **MEGN587** NONLINEAR OPTIMIZATION 3.0
- **MEGN588** INTEGER OPTIMIZATION 3.0
- **MEGN686** ADVANCED LINEAR OPTIMIZATION 3.0
- **MEGN688** ADVANCED INTEGER OPTIMIZATION 3.0

**EENG411** DIGITAL SIGNAL PROCESSING 3.0
**EENG511** CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS 3.0
**EENG521** NUMERICAL OPTIMIZATION 3.0
**MEGN586** LINEAR OPTIMIZATION 3.0
**MEGN587** NONLINEAR OPTIMIZATION 3.0
**MEGN588** INTEGER OPTIMIZATION 3.0
**MEGN686** ADVANCED LINEAR OPTIMIZATION 3.0
**MEGN688** ADVANCED INTEGER OPTIMIZATION 3.0