Engineering Ph.D.

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The Doctor of Philosophy in Engineering degree is offered through the College of Engineering. The most current information on requirements for the degree can be found at: www.coe.montana.edu/graduate_programs.html

Candidates will be admitted to both the College of Engineering and The Graduate School under one of seven options:

Applied Mechanics
This option involves research in areas central to engineering mechanics including solid mechanics, fluid mechanics, thermal mechanics, geomechanics, and structures.

Coordinating Departments: Chemical and Biological Engineering, Civil Engineering, and Mechanical and Industrial Engineering. Typical Research Areas: solid mechanics, fluid mechanics, biomechanics, thermal sciences, structural mechanics.

Chemical Engineering
This option involves research in transport phenomena in complex systems, biofilms, biological materials, and the chemical and biochemical transformation of materials.

Coordinating Department: Chemical and Biological Engineering. Typical Research Areas: extremophilic bioprocessing, in situ biocatalyzed heavy metal biotransformations in natural and engineered biological systems, biomaterials, biochemistry, colloidal system dynamics, metabolic engineering, metabolic systems analysis, biofuels processing, composite materials, durability of materials, surface interactions, catalysis, membrane materials, separations.

Civil Engineering
This option involves research in geotechnical engineering, structural engineering, transportation engineering, environmental engineering, water resources engineering, and construction management.

Coordinating Departments: Civil Engineering and Mechanical and Industrial Engineering. Typical Research Areas: geosynthetics, seismic response of structures and foundations, innovative structural materials, intelligent transportation systems, transportation operations, transportation planning, recycled pavements and base materials, road ecology and constructed wetlands.

Electrical and Computer Engineering
This option involves research in electronic component and system hardware, design, development and theory.

Coordinating Department: Electrical and Computer Engineering. Typical Research Areas: communications, digital electronics, computer engineering, microelectromechanical systems, optics and optical electronics, power systems and power electronics, signal processing, systems and controls.

Environmental Engineering
This option involves research in all areas of the environment including soil, water, and air, with emphasis on microbial interactions with natural and engineered systems.

Coordinating Departments: Chemical and Biological Engineering and Civil Engineering. Typical Research Areas: bioremediation, wetlands, water treatment, wastewater treatment, solid and hazardous waste treatment, biofilm engineering.

Industrial Engineering
This option involves research related to areas of Industrial Engineering.

Coordinating Department: Mechanical and Industrial Engineering. Typical Research Areas: transportation safety, human factors, service systems engineering, virtual reality, health care, ergonomics, leadership and change management, usability engineering, engineering education, and concurrent engineering.

Mechanical Engineering
This option involves research in advance structures and materials, fluid dynamics, and energy systems.


Application and Admission

1. Applications can be submitted online through The Graduate School (http://www.montana.edu/gradschool/apply.html) (all information below will be asked during the online application process and a non-refundable $60 application fee will be required prior to submitting your application)

Minimum College Requirements for Full Admission:
- At least a 3.0 undergraduate GPA.
- GRE scores of Verbal >=152 (53%), Quantitative >=153 (56%) and Analytical Writing >=3.5.
- Favorable letters of recommendation from three references.
- Graduate GPA (if applicable) of 3.2 or better.
- International Students: TOEFL scores of 580 (237 for computer test version) or greater or a minimum International English Language Testing System (IELTS) band score of 7.
- A personal statement of up to 2 pages describing the applicant’s research interests, career research activities (if applicable), and career goals. If the applicant has no direct research experience, they should describe the experiences and activities they have that they believe have prepared them to undertake research.
- A two page CV or résumé describing the applicant’s prior background.

2. Department/s attach summary admission form and circulate application to option coordinator and potential advisers for faculty recommendation.

3. Department Head reviews application in conjunction with faculty recommendation, and exercises one of the following options:
- Full admission - Forward to The Graduate School.
- Provisional admission - Determine conditions that candidate will be accepted and notes actions to be taken, then forwards to The Graduate School
- Reject admission because of academic qualifications.
• Reject admission based on lack of fit with COE research programs or the lack of a potential adviser.

4. Associate Dean responsible for graduate studies in the College of Engineering reviews applications, returns to department for submission to The Graduate School.

5. The Graduate School reviews application to ensure GS standards are met with the following possible options.
   • Accept
   • Reject
   • Return to Department Head and Associate Dean with recommendation for further consideration.

6. Applicant is informed with a letter of acceptance or rejection by The Graduate School.

Acceptance into the program is not always a guarantee of funding (tuition or stipend). Students should establish a dialogue with their chosen department to determine the availability of funding.

If there are course deficiencies that are identified in the student’s educational background, these must be completed prior to full admission (matriculation).

For those entering without having an adviser/major professor previously identified, students should secure an adviser as early as possible, but no later than the end of the third semester of registration in the Ph.D. program. During the selection process, there should be discussions with the student that include an understanding of funding available to the student and the term of commitment.

Degrees Offered

• Ph.D. in Computer Science (http://catalog.montana.edu/graduate/engineering/computer-science/phd-computer-science)
• Ph.D. in Engineering with options in:
  • Applied Mechanics
  • Chemical Engineering
  • Civil Engineering
  • Electrical & Computer Engineering (http://catalog.montana.edu/graduate/engineering/electrical-computer-engineering/phd-electrical-computer-engineering-option)
  • Environmental Engineering
  • Industrial Engineering
  • Mechanical Engineering

Program Requirements

To satisfy the requirements for the Ph.D. in Engineering, the student will take a minimum of 60 credits beyond the bachelor’s degree according to the table below. Different options within the Ph.D. in Engineering and individual graduate student committees may require additional coursework beyond the minimum requirements (see Declared Option Coursework section later in this document).

For students entering with a Masters degree, up to 24 graded credits may be applied (see below). However, the Seminar (ENGR 694) and Rsch & Mthds in Engineering (ENGR 610) requirements and a minimum of 13 additional graded course credits must still be taken at Montana State University. Depending on option requirements, students may have the option (with approval of the committee) of using some of their M.S. credits toward the advanced mathematics and numerical methods requirements.

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>ENGR 694 Seminar</td>
<td>2</td>
</tr>
<tr>
<td>Advanced Mathematics - see declared option coursework *</td>
<td>3</td>
</tr>
<tr>
<td>Numerical Methods - see declared option coursework *</td>
<td>3</td>
</tr>
<tr>
<td>Other Graded Courses - see declared option coursework</td>
<td>24</td>
</tr>
<tr>
<td>Dissertation</td>
<td>18</td>
</tr>
<tr>
<td>Additional Dissertation or Course credits</td>
<td>7</td>
</tr>
</tbody>
</table>

* Course content must be above and beyond that typically required for an undergraduate degree in the student’s Ph.D. option area.

** ENGR 694 should be taken the semester prior to scheduling the comprehensive exams as this seminar class helps the student to prepare the written proposal for their comprehensive.

Total Credits 60

Credits applied from a prior Masters degree must:

• be graded course credits (e.g., not M.S. thesis or independent study credits),
• have a grade of B or higher (or equivalent), and
• be approved by the student’s graduate committee.

Students are expected to attend the COE Seminar Series presentations.

Note for Students Entering Without a Prior Degree in Engineering

If a student enters the Ph.D. program without a prior degree in engineering from an accredited program and is interested in pursuing registration as a professional engineer, they should consult with their department head and major professor to determine what coursework and other experiences may be needed to ensure they are on a pathway to seek licensure. These requirements vary with discipline and the state where licensure is sought.

Examination Requirements

General information about forms required for completion of examinations can be found on The Graduate School (http://www.montana.edu/gradschool/current-grad.html)’s website.

Ph.D. candidates within the College of Engineering at Montana State University must pass a qualifying examination, a comprehensive examination, and a defense of dissertation. The general rules governing these follow. Options may have more specific requirements; see the specifics under option requirements below.

Ph.D. Qualifying Examination

The purpose of the qualifying examination is to determine whether the student has sufficiently mastered the core topics within their chosen area of study. It will be a written examination on undergraduate engineering topics determined by the student’s chosen Ph.D. option area and administered by that option’s committee.

Each Ph.D. Option Committee will offer a qualifying examination annually to students in that option. The qualifying examination will be completed within three semesters but typically within two semesters of full admission (matriculation) into the Ph.D. program. Failure to take the examination in that time period may result in suspension of Ph.D. candidate status, including stipend. The committee will document the results of the examination in a letter to the student, and in the student’s file.
Ph.D. Comprehensive Examination

The purpose of the Ph.D. comprehensive examination is to determine whether the student is ready for independent research in their chosen area of study. The comprehensive examination is administered by the student’s graduate committee (including the Graduate Representative assigned by The Graduate School), and must be completed within two years after passing the qualifying examination. It is also recommended that the student has taken 2/3 of their graded coursework. In addition, students should have completed ENGR 694 prior to taking the exam; the course is designed to assist the student in preparing their proposal.

The Ph.D. comprehensive examination is comprised of:

- A written proposal for the student’s Ph.D. dissertation, and
- An oral presentation of the proposal and oral examination.

The candidate will prepare a written proposal associated with the research topic for the Ph.D. dissertation, in a format designated by the Ph.D. Option. The successful proposal will include a significant literature review, preliminary research to date, and the research proposed to complete the Ph.D. The written proposal will be presented to the student’s graduate committee in advance of the oral presentation, by a date agreed to by the student and graduate committee.

The student will then present the dissertation proposal as a public research seminar that has been advertised to the College of Engineering. This will be followed by a closed-session oral examination by the student’s graduate committee on:

- the candidate’s current and proposed research;
- the candidate’s graduate level understanding of option specific engineering principles; and
- additional topics relevant to the proposed research, including fundamentals of other disciplines drawn upon in the research.

The student’s graduate committee will inform the student of the results of the comprehensive examination immediately following the oral examination and committee deliberation, and will document the results on the appropriate form filed with The Graduate School. A student not passing the comprehensive will have one opportunity to retake the comprehensive after a span of six months has passed. Failure to pass the examination on the second attempt is grounds for dismissal from the Ph.D. program.

There may be additional requirements for these exams specified in the option requirements.

Dissertation Defense

The dissertation defense will consist of two parts: an open seminar of the research results and a closed session with the student’s committee and the graduate representative. Written notification of the results within one week of the defense must be delivered to The Graduate School and the student. Committee members must approve the dissertation, along with the Department Head, and Vice Provost for Graduate Education. Deadline for the dissertation approval is 14 working days before the end of the term for a given semester.

If failure occurs at the first attempt, a second defense must be held. At least six months must elapse before the second examination takes place, with the time period not to exceed nine months. Failure of the second exam will result in suspension from the program.

Graduation Application

An application to graduate is prepared by the student, approved by the major professor, and submitted to The Graduate School through the student’s academic department. Applications are due to The Graduate School September 20th for a Fall Semester graduation, February 5th for a Spring Semester graduation and June 10th for Summer semester graduation.

Declared Option Requirements

Applied Mechanics

Requirements include:

- EM 510 Elastic & Inelastic Analysis I 3
- EM 525 Continuum Mechanics 3
- EMEC 530 Advanced Fluid Mechanics I 3
- EM 560 Finite Elem Analys in Engr 3

The remaining credits are to be established by the student and the major professor in consultation with the student’s graduate committee.

Qualifying Examination: The qualifying assessment will be a written examination on relevant undergraduate level topics. In the Applied Mechanics Option these areas include: Statics, Dynamics, Mechanics of Materials, Fluid Mechanics, Mathematics, Thermodynamics and an Area of Undergraduate Focus (e.g. Structures, Hydraulics, Geotechnology, Material Science, Heat Transfer) - as specified by the candidate prior to the exam. The exam will be one hour per topic area in an open book, open notes format. Students must satisfactorily address four of the submitted topics. Problems will be graded by the faculty member who presented that topic. Students will be provided an opportunity to examine their results, however, in order to protect the questions from dissemination they will not be permanently returned. A grade for the qualifying examination of Pass (P), Fail (F) or Remediate (R) will be given for each candidate. In cases where remediation in certain topic areas is required, the Ph.D. adviser will develop a problem solving based plan with the Ph.D. candidate to prepare for a retest on the identified topic areas. The retest must occur prior to completion of the following semester and will be overseen by the Ph.D. adviser.

Comprehensive Examination: In the Applied Mechanics Option there are two distinct oral examinations: one associated with the Dissertation Proposal and a separate one pertaining to the candidate’s graduate level understanding of Engineering Mechanics principles.

Chemical Engineering

The advanced mathematics and numerical methods classes are specified:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGEN 505</td>
<td>Advanced Engineering Analysis</td>
<td>3</td>
</tr>
<tr>
<td>EGEN 506</td>
<td>Numerical Sol to Engr Problems</td>
<td>3</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECHM 503</td>
<td>Thermodynamics</td>
<td>3</td>
</tr>
<tr>
<td>ECHM 533</td>
<td>Transport Phenomena</td>
<td>3</td>
</tr>
<tr>
<td>ECHM 510</td>
<td>Reaction Engineering/Modeling</td>
<td>3</td>
</tr>
</tbody>
</table>

The remaining credits to be established by the student and the major professor in consultation with the student’s graduate committee.

Qualifying Examination: The qualifier will be a written examination on undergraduate Chemical Engineering including: mass and energy balances, thermodynamics, separations (mass transfer), heat (energy)
transfer, fluids, transport phenomena and chemical reaction engineering. The exam will be 1 hour per topic area question in an open book, open notes format and students will choose 4 subjects which they will solve the problems for, from the 7 problems provided. Each question will be graded by the Faculty member that submitted the question. Students will not be given the test back in order to protect the questions from dissemination. The results will be analyzed by a Committee composed of all Faculty and a grade of Pass (P), Fail (F) or Remediate (R) given each candidate. In cases where remediation in certain topic areas is required, the Ph.D. adviser will develop a problem solving based plan with the PhD candidate to prepare for a retest on the identified topic areas. The retest must occur prior to the next fall semester and will be overseen by the Ph.D. adviser. The qualifying exam must be completed within two semesters of matriculation into the Ph.D. program. Failure to take the exam in that time period may result in suspension of Ph.D. candidate status, including stipend. The exam will be administered on the second Tuesday in February of the Spring semester to all students required to take the exam in a year.

Comprehensive Examination: The proposal will be in the NSF format, in compliance with the current year’s grant proposal guidelines (gpg) at www.nsf.gov (http://www.nsf.gov). A written exam on graduate level thermodynamics, transport phenomena, mathematical methods, and kinetics and reactor engineering will be required of graduate students who have a GPA in graduate coursework of less than 3.5. A public oral seminar of 40 minutes plus 10 minutes of public questions, on the research to date and proposed research to complete the Ph.D., will be given by the Ph.D. candidate. This will be followed by a closed-session oral examination of 45-90 minutes by the student’s Ph.D. committee.

Civil Engineering
Students must meet the overall requirements for the Ph.D. in Engineering. The student’s committee may require additional credits of study based on the student’s background and needs. Specific course selections will be determined by the student and his/her committee to support the student’s area of study. Up to 24 graded course credits can be applied from an M.S. Degree in meeting the Ph.D. credit requirements, at the discretion of the student’s Ph.D. committee.

Qualifying Examination: The diversity of backgrounds of students pursuing this option requires that the qualifying examination subject material and to some extent format be responsive to these backgrounds. The exam will be administered during an 8-hour period of mutual agreement between the adviser, student and PhD option coordinator. The student will be given a packet of up to 10 questions on undergraduate Civil Engineering topics appropriate to the sub-discipline of the proposed research and related topics. Each problem will be designed to be solved in about an hour, and the student must submit 6 solutions. Problem solutions will be graded by the faculty member who presented that topic. Students will be provided an opportunity to examine their results, however, in order to protect the questions from dissemination they will not be permanently returned. A grade for the qualifying examination of Pass (P), Fail (F) or Remediate (R) will be given for each candidate. In cases where remediation in certain topic areas is required, the Ph.D. adviser will develop a problem solving based plan with the Ph.D. candidate to prepare for a retest on the identified topic areas. The retest must occur prior to completion of the following semester and will be overseen by the Ph.D. adviser. Students may apply for a Ph.D. qualifying examination waiver (for instance if they have completed the Master of Science written comprehensive examination at Montana State University in the same sub-discipline as is the focus of their proposed Ph.D. studies).

Comprehensive Examination: The proposal should be in the NSF format, in compliance with the current year’s grant proposal guidelines (gpg) at www.nsf.gov (http://www.nsf.gov) unless otherwise agreed to by the student’s committee. A public oral seminar of 30 to 40 minutes plus 10 minutes of public questions, on the research to date and proposed research to complete the Ph.D., will be given by the Ph.D. candidate. This will be followed by a closed-session oral examination of up to 2 hours administered by the student’s Ph.D. committee. A written exam on graduate level environmental engineering topics may be required of graduate students who have a GPA in graduate coursework of less than 3.5.

Electrical and Computer Engineering
Within the course credits, students must take courses in at least 3 of the following 6 areas: Digital Systems, Signals and Controls, Electromagnetic Fields and Optics, Communications, Power and Power Electronics, and MEMS and Electronics. The remaining credits to be established by the student and the major professor in consultation with the student’s graduate committee.

Environmental Engineering
Of the credits in the Option Coursework noted above, 12 credits from the following subset of courses are required, with no more than 6 credits at the 400 level. Equivalent courses from prior MS degrees may be used to satisfy this requirement.

EENV 441 Natural Treatment Systems 3
EENV 443 Air Pollution Control 3
EENV 445 Hazardous Waste Treatment 3
EENV 447 Hazardous Waste Management 3
EENV 534 Environ Eng Investigation 3
EENV 540 Water Chemistry for Envr Engr 3
EENV 561 Environ Eng Reactor Theory 2
EENV 562 Water Treatment Process/Design 3
EENV 563 Wastewater Treat Proc/Design 3
ECIV 529 Groundwater Contamination 3
EENV 565 Chem Sens/Instr Envir Biotech 2
EBIO 566 Fundamentals of Biofilm Engr 3

The remaining credits are to be established by the student and the major professor in consultation with the student’s graduate committee.

Qualifying Examination: The diversity of backgrounds of students pursuing this option requires that the qualifying examination subject material and to some extent format be responsive to these backgrounds. The exam will be administered during a 6-hour period of mutual agreement between the adviser, student and PhD option coordinator. The student will be given a packet of questions on undergraduate Environmental Engineering topics including: Water Quality Parameters, Water Chemistry, Drinking Water Treatment, Wastewater Treatment, Reactors/Kinetics/Stoichiometry, Hydraulics, Porous Media Flow & Groundwater Contamination, Air Pollution Control & Air Quality, Solid & Hazardous Waste Management, Fluid Mechanics, Transport Phenomena, Thermodynamics. The exam will be open book, open notes format. Each question the student choses to answer will be graded by the Faculty member that submitted the question. The results will be analyzed by a Committee composed of the Environmental Engineering Faculty and a grade of Pass (P), Fail (F) or Remediate (R) will be
given to the candidate for each topic. In cases where remediation in certain topic areas is required, the Ph.D. adviser will develop a problem solving based plan with the Ph.D. student to prepare for a retest on the identified topic areas. The retest must occur within six months and will be overseen by the Ph.D. adviser. Students may apply for a Ph.D. qualifying examination waiver (for instance if they have completed the Master of Science written comprehensive examination at Montana State University in Environmental Engineering).

**Comprehensive Examination:** The proposal should be in the NSF format, in compliance with the current year’s grant proposal guidelines (gpg) at www.nsf.gov unless otherwise agreed to by the student’s committee. A public oral seminar of 30 to 40 minutes plus 10 minutes of public questions, on the research to date and proposed research to complete the Ph.D., will be given by the Ph.D. candidate. This will be followed by a closed-session oral examination of up to 2 hours administered by the student’s Ph.D. committee. A written exam on graduate level environmental engineering topics may be required of graduate students who have a GPA in graduate coursework of less than 3.5.

**Industrial Engineering**

Ph.D. candidates under the IE Option must take a minimum of 30 credits of 500-level courses that includes the following coursework with a grade of B or better:

The advanced mathematics and numerical methods classes are specified:

- EGEN 505, EIND 555, or EIND 557 Advanced Mathematics
- EIND 509 Numerical Methods

Students must take at least 6 credits from each of the three emphasis areas:

- Human Factors (e.g., EIND 510, EIND 511, EIND 513, EIND 514)
- Systems Modeling (e.g., EIND 509, EIND 557)
- Service Engineering (e.g., EIND 506, EIND 525, EIND 574)

The remaining credits to be established by the student and the major professor in consultation with the student’s graduate committee.

**Qualifying Examination:** The exam will be administered on the second Tuesday in February of the Spring semester. Students will be examined on the following three Industrial Engineering topics: engineering probability & statistics (e.g. EIND 354), work design & analysis (e.g. EIND 313), and engineering economy (e.g. EGEN 325). Additionally, students will choose from one of the following Industrial Engineering topics: principles of operations research (e.g. EIND 364), ergonomics and human factors engineering (e.g. EIND 413), or engineering management & ethics (EIND 300). The exam will be 5 hours duration in an open book, open notes format. Each problem set will be graded by the faculty member that submitted the set. The results will be analyzed by the Mechanical Engineering graduate studies committee, and each candidate will receive a grade of Pass (P), Fail (F) or RemEDIATE (R). Students will not be given the test back in order to protect the questions from dissemination. In cases where remediation in certain topic areas is required, the Ph.D. advisor will develop a problem-solving-based plan with the Ph.D. candidate to prepare for a retest on the identified topic areas. The retest must occur prior to the next fall semester and will be overseen by the Ph.D. Advisor.

**Comprehensive Examination:** The public research seminar will include 40 minutes for the student’s presentation and 10 minutes for questions from the audience. This will be followed immediately by a closed-session oral examination of 45-90 minutes by the student’s Ph.D. committee and additional remediation may be required at this point.

### Mechanical Engineering

The advanced mathematics and numerical methods classes are specified:

- EGEN 505 Advanced Engineering Analysis 3
- EGEN 506 Numerical Sol to Engr Problems 3

Requirements include:

- EM 525 Continuum Mechanics 3
- Thermo-fluids Mechanics 3
- Solid Mechanics 3

The remaining credits to be established by the student and the major professor in consultation with the graduate committee.

**Qualifying Examination:** The exam will be administered on the second Tuesday in February of the Spring semester. The undergraduate Mechanical Engineering topics will include: Thermodynamics, Heat (energy) transfer, Fluid Mechanics, Structural Mechanics, Materials, Dynamics and Vibrations, and Mathematics. Students will solve problems in 4 of the 7 topic areas. The exam will be 5 hours duration in an open book, open notes format. Each problem set will be graded by the faculty member that submitted the set. The results will be analyzed by the Mechanical Engineering graduate studies committee, and each candidate will receive a grade of Pass (P), Fail (F) or Remediate (R). Students will not be given the test back in order to protect the questions from dissemination. In cases where remediation in certain topic areas is required, the Ph.D. advisor will develop a problem-solving-based plan with the Ph.D. candidate to prepare for a retest on the identified topic areas. The retest must occur prior to the next fall semester and will be overseen by the Ph.D. adviser.

**Comprehensive Examination:** The public research seminar will include 40 minutes for the student’s presentation and 10 minutes for questions from the audience. This will be followed immediately by a closed-session oral examination of 45-90 minutes by the student’s Ph.D. committee and additional remediation may be required at this point.
Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

Times was used instead of Adobe Garamond Pro.

The editor may contact Leepfrog for a draft with the correct fonts in place.