GRADUATE STUDENT HANDBOOK

Electrical and Computer Engineering Department

Montana State University

This handbook provides guidelines for the electrical and computer engineering graduate program at Montana State University – Bozeman. In the event of an inconsistency, all Graduate School and Montana State University policies take precedence. Applicants and students should refer to the Graduate School webpage (http://www.montana.edu/gradschool/).

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1.1 Overview

Welcome to graduate study in the Electrical and Computer Engineering (ECE) department at Montana State University! We are a dynamic department with world-class faculty conducting nationally and internationally recognized research in exciting, interdisciplinary fields. Our faculty value excellence in teaching and research, providing an outstanding opportunity for graduate and undergraduate students to extend their classroom learning to exciting real-world applications. Our department enrolls typically 40 graduate students, among a population of approximately 2000 graduate students and 13,000 undergraduate students at Montana State University (MSU), which is particularly well known for its excellent engineering and science programs. Since 2006 MSU has been designated one of the top 94 U.S. universities with "very high research activity" by the Carnegie Foundation for the Advancement of Teaching.

MSU is located in Bozeman, Montana, a vibrant small city in southwestern Montana (45.7°N, 111.0°W), approximately 145 km (90 mi) north of Yellowstone National Park, immediately adjacent to large regions of national forest and dramatic mountains. The Bozeman area provides unparalleled opportunities for outdoor recreation, while also being home to a number of technology companies, most specializing in optics, electronics, software, and biotechnology. Many of these companies have their roots in MSU graduate research programs and often interact closely with our students and faculty. These factors all combine to produce a unique opportunity for graduate students to gain world-class training with personalized attention.

The purpose of this handbook is to orient you to the available graduate degree options and to guide you through the process of obtaining a graduate degree in our department. Each student has the responsibility of working with his or her graduate advisor to ensure that all requirements are met in their degree program. The Graduate School policies will prevail in the event of a conflict with the policies described here, although please note that the ECE department has several policies that go beyond the Graduate School minimum requirements. See the webpage for The Graduate School for more information: http://www.montana.edu/gradschool.

1.2 Degree options

The ECE department offers three degrees at the graduate level:

1) **Doctor of Philosophy** (Ph.D.) in Engineering with Electrical Engineering Emphasis;
2) **Master of Science** (M.S.) in Electrical Engineering (thesis or professional paper option);
3) **Master of Engineering** (M.Eng.) in Electrical Engineering (coursework-only degree).

The **Ph.D.** is granted in recognition of advanced accomplishment and original contribution to the field. The Ph.D. is the highest academic degree and is a research-intensive program. This degree requires completion of 42 approved course credits beyond the undergraduate degree and 18 credits of dissertation research (up to 24 graded course credits can be applied from a previous master's degree). The primary requirement is to demonstrate the ability to conduct independent research, draw logical conclusions, and communicate the results effectively in written and oral form. See chapter 3 for details of the Ph.D. program.

The **M.S.** degree requires 30 total credits, including research experience reported in either a thesis (plan A) or a professional paper (plan B). Generally, plan-A students focus more heavily on research and plan-B students on professional practice. Plan A requires twenty (20) credits of acceptable courses and ten (10) credits of research that leads to a thesis, which is defended orally before the student's graduate committee and the public. Plan B requires twenty-seven (27) credits of acceptable courses and three (3) credits of project work that is reported in a professional paper approved by the student's advisor and typically presented to the committee and the public. See chapter 4 for details of the M.S. degree program.

The **M.Eng**. degree requires 30 credits of courses with no research paper or thesis. See chapter 5 for details of the M.Eng. degree program.

1.3 Admissions

Minimum requirements

Minimum requirements for admission to the ECE graduate program are as follows (the majority of admitted students have GPAs and GRE scores in excess of these minimum values):

- undergraduate degree in ECE or closely related field;
- cumulative grade-point average (GPA) ≥ 3.0 on a scale of 4.0 for M.S. admission;
- graduate school GPA ≥ 3.2 for Ph.D. admission after previous graduate studies;
- *Graduate Record Exam* (GRE) scores:
    - Quantitative ≥ 153 (680 prior to 1 Aug. 2011)
    - Verbal ≥ 152 (480 prior to 1 Aug. 2011)
    - Analytical writing ≥ 3.5
- three (3) **reference letters** from professors and others qualified to assess the applicant's academic achievements and potential for success in an ECE graduate program (letters should be submitted directly by the writer);
- one-page **statement of purpose** written by the applicant, listing specific areas of research at Montana State University in which the applicant is interested in participating (this is a very important component that is used to identify research opportunities);
- *Test of English as a Foreign Language* (TOEFL) ≥ 250 computer, 600 paper (for applicants from countries where the official language is other than English).

Admission to the ECE graduate program requires meeting the published thresholds for grades and test scores, but is also heavily dependent on other factors including reference letters, and for the research-based M.S. and Ph.D. programs, availability of a suitable graduate advisor, a match between an applicant's stated interests and ongoing research work, and the relative supply and demand of students in various areas. Admission decisions are made by the ECE graduate committee, and become official upon approval by the Graduate School. If necessary and compatible with offered support, admitted students may defer their admission date by up to one year (a student who attends another educational institution during the deferment period must submit transcripts from that institution before enrolling at MSU).

Direct admission to Ph.D. program

Students with particularly strong undergraduate records are eligible for admission directly to the Ph.D. program without first obtaining a master's degree. A minimum undergraduate grade point average (GPA) of 3.3/4.0 is required. Students wishing to pursue this option should clearly indicate this in their statement of purpose. Applicants also can indicate in their statement of interest if they wish to earn a master's degree enroute to a Ph.D.

Converting admission status

Students are admitted to a specific degree program. The following procedures must be followed to convert from the original program to another graduate program in our department.

Continuing to Ph.D. from M.S.

A student admitted to the M.S. program who wants to continue as a Ph.D. student must submit a written request to the ECE graduate and research committee, describing their intended Ph.D. subject area and proposed advisor. This request must include a copy of their M.S. transcripts, a recommendation letter from the M.S. advisor, and a letter from the proposed Ph.D. advisor. If a review of these materials leads to a decision to admit the student to the Ph.D. program, the committee will authorize the student to submit a *Change in Graduate Status* form (available online) to the Graduate School to officially change their status from M.S. to Ph.D.

Converting to Plan-B M.S.

In situations with significant extenuating circumstances and with approval of the advisor and supervisory committee, a student can convert to a plan-B Master's program from either a Plan-A Master's or a Ph.D. program. The department allows students who change to plan B to count up to three (3) previously completed credits of *Doctoral Thesis* (EELE 690) or *Master's Thesis* (EELE 590) in place of the required *Professional Paper/Project* (EELE 575) credits, but the paper must still be completed. In this case the student submits a new *program of study* that lists all coursework, the original three (3) EELE 590 or EELE 690 credits, and one (1) or more additional credit(s) of *Independent Study* (EE 592) that is granted upon approval of their professional paper (the primary purpose of the 592 credit is for the advisor to award a grade for the paper and for indicating to the Graduate School that the paper has been completed). The new Plan-B *program of study* must be submitted to the Graduate School along with a memo from the student's advisor requesting substitution of EELE 590/690 plus a credit of EELE 592 in place of EELE 575. When converting from a Ph.D. to a master's program, a student should use the *Change in Graduate Status* form to notify the Graduate School of their choice (any use of this form in the ECE department requires approval by the advisor and the ECE graduate committee).

Converting from M. Eng. to M.S. or Ph.D.

Students in the M. Eng. degree program wishing to transfer to the Master of Science or Ph.D. program must reapply to the ECE Department graduate program.

Converting to M.Eng.

Current M.S. and Ph.D. students wishing to transfer to the M. Eng. program must petition for change of status and program. This petition needs to be approved by the student's research advisor, graduate coordinator, and department head. Additionally, a student who does not pass the graduate qualifying exam in two attempts or who does not identify a viable research project by the end of the 2nd semester in residence will be transferred to the M.Eng. program.

Application deadlines

We accept applications throughout the year, but for full consideration of admission with financial support, domestic and international students' complete applications must be received by the following priority deadlines:

Priority application deadline	for admission in
January 15	Summer or Fall
September 15	Spring

Applications for admission in a semester for which the priority deadline has passed will be considered on a space-available basis if received by the following university deadlines:

Domestic students	*International students*
July 15 for fall	May 15 for fall
December 1 for spring	October 1 for spring
April 1 for summer	February 1 for summer

Applicants will be evaluated for admission only after submitting a complete application for graduate admission along with the application fee. We cannot estimate an applicant's probability of admission before an application is submitted (but prospective students can and should communicate with faculty members regarding the potential availability of research projects).

Application procedure

Applicants should use the online application at http://www.montana.edu/wwwdg/apply.html, which will generate emails requesting online submission of reference letters.

Undergraduate degree not in Electrical or Computer Engineering

We encourage well-qualified applicants with degrees in physics, optics, mathematics, computer science or other closely related fields to apply if they are interested in pursuing graduate studies in ECE. Many of our research programs cross boundaries of traditional disciplines and good students from allied fields often do well in ECE. All applicants, regardless of undergraduate discipline, are expected to have completed mathematics courses including differential calculus, integral calculus, multivariable calculus, and differential equations, and at least two semesters of calculus-based physics. Primarily because of inadequate training in mathematics and physics, a bachelor's degree in **electrical engineering technology** (BSEET) does not provide adequate training for graduate study in electrical engineering; students with this degree should apply to the ECE undergraduate program.

Students with non-ECE undergraduate degrees are required to demonstrate proficiency in several core areas of the ECE curriculum before completing their graduate degree. This can be accomplished by having taken an equivalent class previously or by passing the class with a grade of B or better at MSU. Deficiency courses will be determined for each student by the supervisory committee based on the student's background, experience, and professional goals, typically requiring demonstration of proficiency in two to four of the following courses (which may also require prerequisite courses):

- EELE 308 Signal and System Analysis
- EELE 317 Electronics
- EELE 321 Introduction to Feedback Controls
- EELE 334 Electromagnetic Theory I
- EELE 355 Electric Machinery Fundamentals
- EELE 371 Microprocessor Hardware and Software

Transfer credit

A maximum of nine (9) credits of committee-approved graduate courses from another institution can be transferred into the ECE graduate program. The nine-credit limit includes courses taken as an undergraduate student and reserved for graduate credit, courses taken as a graduate student in another department or at another university, and courses taken while in non-degree status. A student's supervisory committee also can approve up to 24 graded course credits from a previously earned master's degree to be counted on a Ph.D. program of study.

1.4 Financial Support

The majority of graduate students in our program receive financial support through teaching and research assistantships that provide opportunities for graduate students to develop and practice teaching skills and to participate in externally funded research projects. All applicants are considered for financial support without submitting any additional application.

1.4.1 Research Assistantships (RAs)

Research assistantships provide financial support to graduate students who work on externally funded research projects. The funding for RAs comes directly from grants obtained by individual faculty through a competitive proposal process, and is therefore available only for specific projects. The level of financial support provided by an RA may vary according to available funds on a specific project, but generally pays a stipend and tuition.

Students are chosen by individual faculty members to receive RA support based on the project's needs and the student's interests, capabilities, and accomplishments. The sponsoring faculty member typically serves as the advisor and supervisory committee chair for a student supported by their RA funds. Faculty members may end RA support for a student for reasons that include, but are not necessarily limited to, the grant ending, insufficient research or academic progress by the student, or failure of the student to remain in good academic standing.

Work performed by students with RA support varies according to project needs, but typically addresses one or more independent portions of the research project and forms the basis of the student's thesis or dissertation. RAs are expected to follow the guidance of their advisor and to exercise independent motivation in exploring the research topic by discussing the research with other

project participants, exploring relevant research literature, proposing alternate approaches to the project, carrying out modeling and simulation efforts, conducting experiments, analyzing results, drawing conclusions, and disseminating results through oral presentations and written publications. RAs may also work with other graduate and undergraduate students, faculty, and staff, including helping to guide the learning and work of undergraduate students.

RA funds are not provided as payment for hourly work, but rather as support for a student whose job it is to make satisfactory progress toward completion of their research project and the academic requirements of their graduate degree. As general guidelines, a student should expect to work approximately half time on their research project while taking classes (typically 6-9 credits each semester) and to work full time on their research project when not taking classes (the latter also applies to summer terms when the student is offered summer RA support). It is common for graduate students' course loads to reduce as the student proceeds into their graduate degree program, to a point where they register only for thesis or dissertation research credits by their final semester. As this occurs, the time they spend on research should increase accordingly.

Responsible Conduct of Research Training

All Graduate Research Assistants supported by grants from the National Science Foundation and the National Institutes of Health (NIH) are legally required to complete training in the responsible conduct of research (i.e. research ethics). This training is available in at least two formats:

- Online … http://www.montana.edu/research/osp/index.html#video
- Classroom … PHL 591 Research Ethics (1-credit, 8 week class)

1.4.2 Graduate Teaching Assistantships (GTAs)

Graduate teaching assistantships provide financial support to graduate students who work with faculty members to help teach classes, grade homework, supervise laboratory sessions, and otherwise support the overall instructional effort. Ph.D. students are particularly encouraged to spend some time during their graduate program as a TA to obtain teaching experience. Graduate TAs typically work half time during the academic year and are provided a monthly stipend during the academic year and a tuition waiver (non-tuition fees often must still be paid by the student).

To qualify for GTA support, international students must pass either the *Test of English as a Foreign Language* internet-based (TOEFL IBT) with a minimum score of 100 or the *International English Language Testing System* (IELTS) with a minimum score of 7.0. All graduate students with GTA support are required to register for a minimum of six (6) credits during each supported semester.

Funds are provided by the ECE department for a limited number of GTA positions each year. GTAs normally are offered as short-term support while a student seeks a research project, finishes work on a thesis or dissertation, or gains desired teaching experience.

1.5 Academic Standards and Retention

Graduate students are required to maintain a cumulative 3.0 GPA in their graduate program and to achieve at least a 3.0 GPA each semester. The Graduate School will place students on probation as a warning for obtaining a semester GPA below 3.0, for not having a program of study approved by the deadline, or when the faculty feels the student is not making satisfactory progress toward their

degree. A student is placed on university probation for failing to maintain a cumulative graduate GPA above 3.0, failing to successfully complete with a grade of B or better the majority of courses each semester, or for not meeting departmental or Graduate School provisions of admission.

The Graduate School suspends (dismisses from the program) a student whose semester, cumulative, or graduate-program GPA falls below 3.0 after university probation, who does not meet admission provisions, or who fails to progress satisfactorily through the program. Students admitted provisionally may be suspended without a probationary period if the provision for admission has not been met. Students may also be suspended for failing to maintain a 3.0 cumulative graduate GPA for two (not necessarily consecutive) semesters without a previous probationary status.

According to department policy, students may lose financial support if their academic or RA performance is deemed unsatisfactory by their advisor or if their TA duties are deemed unsatisfactory by the supervising faculty. All graduate students must submit a *program of study and supervisory committee* form, which identifies a faculty advisor who will supervise their dissertation, thesis, or professional paper and lists the courses to be taken, by the end of their second semester in residence or they will be ineligible for financial support and may be dismissed from the program.

Academic misconduct by graduate students in the ECE department will be dealt with in accordance with MSU policies (http://www2.montana.edu/policy/student_conduct/student_conduct_code.htm). The published definition of academic misconduct includes the following items of particular significance to graduate students: cheating; plagiarism; falsification; multiple submissions; unauthorized access to, manipulation of or tampering with laboratory equipment, experiments, computer programs without proper authorization; and misuse of research data in reporting results.

1.6 Registration Requirements

Graduate students are expected to become familiar with and follow the Graduate School registration policies. The following is a brief summary of some of the more relevant ones:

- graduate students must register for nine (9) credits per semester to be considered full time;
- graduate students cannot register for more than fifteen (15) credits per semester;
- graduate students must register for at least three (3) credits in any semester in which they take a graduate qualifying or comprehensive exam or in a semester when they graduate.
- international graduate students must register for at least nine (9) credits every semester except the semester of graduation, or as permitted by the Office of International Programs and the Graduate School;
- graduate students must register for three (3) credits in any summer term after completion of any part of the comprehensive exam or (for M.S. students only) after completing all non-thesis courses approved on the program of study.

1.7 Graduate Study Qualifying Examination

Any student admitted to either the M.S. or Ph.D. program must take the written qualifying examination the first time it is offered following their admission. Students entering from a non-ECE background may petition the Graduate Coordinator for a one-semester extension. The exam will be typically offered on the third or fourth Thursday of Fall and Spring Terms. This exam covers material that we expect research students to know from their undergraduate training. As is

outlined below, each student must answer the Math Section (2 problem sets) and Core Section (1 problem set each), then select one problem set to answer in the Elective Areas. Eight problem sets will be graded: 2 Math, 5 Core and 1 Elective.

Math (required)	Core Areas (required)	Elective Areas (select one)
2 parts	1. Circuits	1. Controls
	2. Signals	2. Power & Energy
	3. Electronics	3. Digital Systems
	4. Electromagnetics	4. Applied Electromagnetics
	5. Digital Logic	5. Communications
		6. Digital Signal Processing

Format: This is a closed-book exam. The math section is completed without a calculator and turned in, and then calculators are allowed for the remaining subject areas.

A list of representative topics and textbooks is available at the ECE department office.

A student who does not pass the exam the first time at the required level (typically 60% for MS and 80% for PhD) will be offered a second opportunity to take the exam, but must do so the next time it is offered. A student who does not pass at an acceptable level in two attempts can elect to continue as a M.Eng. student but not as a M.S. or Ph.D. student.

2. Ph.D. Requirements and Procedures

The ECE Department Ph.D. requirements are designed to conform to both the Graduate School policies (http://www.montana.edu/gradschool/catalog.html) and College of Engineering Ph.D. policies (http://catalog.montana.edu/graduate/engineering/engineering-phd/#programstext).

2.1 Committee

Admission to the Ph.D. program requires sponsorship by a faculty member who serves as the student's advisor and chair of the supervisory committee. By the end of the second semester in residence, the student must choose their supervisory committee members in consultation with their advisor and file a *program of study* approved by the full committee. The Ph.D. supervisory committee has overall responsibility for guiding the student toward successful completion of the degree and for examining the student at several points throughout the degree program. Each committee member participates in and judges the student's performance in the comprehensive examination and the dissertation defense and final examination.

The Ph.D. supervisory committee consists of at least four (4) members (including the chair) chosen by the student and advisor, and approved by the Graduate School. The committee chair is normally the advisor, who must be a tenure-track faculty member in the ECE department at MSU-Bozeman. The other three members can be chosen from the faculty of the ECE department and allied departments related to the student's research work. The majority of the committee must be from the ECE tenure-track faculty. It is common for Ph.D. students to conduct interdisciplinary research, in which case the committee should include a representative of the collaborating department. For a committee member from outside the MSU faculty to be included on the committee, a vita must be submitted to the Graduate School for approval.

2.2 Program of Study

The *program of study* form must be completed by the student and approved by the supervisory committee and the Graduate School before the end of the second semester in the graduate program. Failure to meet this deadline constitutes lack of progress toward the graduate degree and is grounds for probation, suspension of financial support, and possibly dismissal from the graduate program. This form lists all courses to be taken by the student for their graduate degree (except deficiency courses and any additional courses that the supervisory committee requires of the student to correct deficiencies and weaknesses). Ph.D. students should consider including courses in their program of study from appropriate departments outside of ECE that are relevant to their research.

A previously earned master's degree should be listed on the first page of the *program of study*. The COE Ph.D. policies allow the use of up to twenty-four (24) graded course credits from a master's degree (with a grade of *B* or higher). The exact number is to be decided by the academic advisor and supervisory committee. Master's degree courses that are approved for use toward a Ph.D. are not listed on the *program of study* form (if a previous master's degree is listed on page one, the Graduate School automatically allows up to 30 credits toward the Ph.D., but the exact number of credits is decided by the student's committee). If the master's degree was earned elsewhere, a Ph.D student is required to complete at least 13 major course credits at Montana State University. With approval of their supervisory committee, students may use appropriate M.S. courses to satisfy the advanced math and numerical methods requirements.

A Ph.D. program of study must include the following:

- Total ≥ **60** credits
  - All PhD credits no more than ten (10) years old at time of graduation (this limit does not apply to courses counted from a previously earned master's degree).
  - **3** credits *Research & Methods in Engineering* (ENGR 610) in 1st semester.
  - **2** credits *Seminar* (ENGR 694), taken just before Comprehensive Examination.
  - **3** credits Advanced Math (committee-approved course focusing on mathematical or numerical methods, typically satisfied by either 4xx and higher math courses or math-methods graduate engineering courses).
  - **3** credits Numerical Methods (committee-approved).
  - **18** credits *Dissertation* (EELE 690).
  - ≥ **24** course credits:
    - ≤ 9 credits at 4xx level (beyond master's degree courses).
    - up to 24 graded course credits with grade of B or better from a previously earned master's degree can be approved by the student's committee (these classes do not have to be listed explicitly on the program of study form).
  - **7** additional credits of graded coursework or dissertation (EELE 690).

All credits must also meet the following conditions:

- ≤ 6 credits *Independent Study* (EELE 592).
- ≤ 3 credits pass/fail, excluding dissertation.
- ≤ 9 credits challenged.
- No credits of 488, 489, 490, 492, 494, 498, 575, or 589 are allowed.
- Regardless of how many course credits are applied from a previously earned master's degree, the PhD program of study must include at least 13 credits of major courses taken at Montana State University.

2.3 Timeline

<u>At admission</u>
Select advisor

<u>During the first year</u>
Pass the qualifying examination (see section 1.7).

<u>By the end of the second semester of Ph.D. enrollment</u>
Select committee members and submit *program of study* approved by supervisory committee.

<u>By end of the affected semester</u>
File changes to the *program of study* with the Graduate School.

<u>Within two years of the qualifying examination and after completing 2/3 of coursework</u>
Pass the *comprehensive examination* (must be registered for ≥ 3 credits in exam semester).

<u>In the graduation term</u>

- Register for ≥ 3 credits.
- Submit *Application for Advanced Degree* to the Graduate School (**by September 20 for**

Fall, February 5 for Spring, or June 10 for Summer).

- Schedule *Comprehensive Oral Exam and Dissertation Defense* (**two weeks before exam**).
- Deliver completed dissertation to supervisory committee (**at least two weeks before exam**).
- Pass *Comprehensive Oral Exam and Dissertation Defense* **(at least two weeks before end of term and no more than five years after comprehensive examination).**
- Make modifications and corrections to dissertation as required by your committee (**in time to be approved by the Graduate School at least two weeks before end of term**).
- Submit CD containing electronic dissertation approved by your committee to the ECE department (**at least two weeks before end of term**).
- Submit ECE-approved electronic dissertation, *Electronic Thesis/Dissertation Approval Form* signed by all committee members, and *Thesis/Dissertation/Professional Paper Report* signed by the ECE department head, to the Graduate School **(in time to be approved at the Graduate School at least two weeks before end of term**).

Note that several items must be completed at least two weeks before the end of the graduation term, but there can be significant delays between completing each item. For example, it typically takes one week or longer after the dissertation defense before the dissertation can be submitted to the Graduate School; it also can take several days to obtain Graduate School approval (at least 2 weeks before the end of the graduation term). In other words, it is essentially impossible to meet graduation deadlines if the dissertation defense is held later than three weeks before the end of the term.

2.4 Ph.D. Examinations

There are three major examinations to be completed by a Ph.D. student. The objectives and procedures for these examinations are described here.

2.4.1 Ph.D. Qualifying examination

Description:
Each Ph.D. student must pass the graduate study qualifying examination, a written test of the student's preparation in mathematics and fundamental ECE topics at the undergraduate level. See section 1.7 for details.

Timing:
Ph.D. students must take the qualifying exam during their first year of registration in the Ph.D. program. A one-semester delay may be requested by students who enter from non-ECE programs. The exam is offered once each fall and spring semester, typically in the third week.

2.4.2 Comprehensive examination

Description:
The comprehensive examination is a written and oral examination conducted by the supervisory committee to test the student's preparation for conducting independent research, assess his or her likelihood of successfully completing a Ph.D. research project, and examining the student's abilities to successfully communicate research objectives, procedures, and results.

At least one week before the exam the student must provide to each member of the supervisory committee a written research plan, which typically forms the basis of the first chapter of the dissertation. The first portion of the exam is a public oral presentation by the student of the research plan. The plan must describe the student's research topic, its relevance and relationship to other work in the field, the proposed research methods, the student's qualifications and preparation to perform the entire project, and the anticipated significance of the results.

The second portion of the exam is an interactive oral examination, attended only by the supervisory committee and the student, in which the supervisory committee asks questions to probe the student's comprehensive knowledge and preparation based on his or her record of graduate course work. The committee should also address the research proposal by asking questions, providing advice, clarifying any misunderstandings, and generally assessing the student's ability to complete the proposed work.

At the conclusion of the exam the supervisory committee will convene alone to determine whether the student has passed or failed. The committee will then immediately inform the student either that he or she has passed, or that the committee will reconvene once the student has met specified conditions.

Timing:
The comprehensive exam must be taken within two years of passing the qualifying exam but at least one semester prior to the dissertation defense. Typically two-thirds of the student's course work is completed before the comprehensive exam.

2.4.3 Dissertation defense

Description
The objective of the dissertation defense is to examine the student's level of accomplishment in research and his or her ability to communicate this research work and results in a professional manner at the level of an independent professional researcher. The dissertation defense is supervised by the student's Ph.D. committee chair.

The first part of the exam is held in a public meeting where the Ph.D. student gives an oral presentation describing and summarizing the dissertation project. This public presentation should not last more than one hour, including a question-and-answer period during which attendees may ask questions about the presentation. The public presentation is followed by a private meeting with the supervisory committee and student. The committee, the ECE department head, and the Graduate School must approve the dissertation before the Ph.D. degree can be conferred.

Timing:
The dissertation defense is held upon completion of all course work and the dissertation. The defense must be held within 5 years of the comprehensive exam and at least fourteen (14) days before the end of the semester of graduation. There should be at least one semester between completion of the comprehensive examination and the dissertation defense.

2.5 Dissertation guidelines

The Ph.D. dissertation is a detailed report of original research conducted by the graduate student with guidance from his or her advisor and supervisory committee. It must have significant scope, depth, and novelty, such that at least selected results can be published in one or more peer-reviewed archival journals. There is no mandatory number of publications required, but journal publications must result from a Ph.D. project.

All dissertations at Montana State University are submitted in electronic form, so the student can use color figures and even multimedia as appropriate. For details on format and submission requirements, the student is referred to the Graduate School (specific format requirements are at http://www.montana.edu/etd/ but each student chooses a reference style following the standards of a journal in their field). Each student must also submit an electronic copy of their dissertation to the department before graduating.

3. MS with Thesis (Plan A) Requirements and Procedures

The thesis-based (plan-A) Master of Science (M.S.) degree in electrical engineering is a research-oriented degree intended to provide the student advanced education that goes deeper than the undergraduate degree and to provide the student with experience working on a cutting-edge engineering research project. All plan-A M.S. students must conduct a research project that is reported in a written thesis and defended at the Comprehensive Oral Examination prior to graduation. Most plan-A M.S. students conduct their research with support from a research assistantship provided by faculty research funds.

3.1 Supervisory Committee

Each M.S. student is responsible for finding an appropriate research project and research advisor. The advisor usually is the faculty member whose research grant provides RA funding. By the middle of their second semester in the graduate program, each student must choose their supervisory committee members, in consultation with their advisor who serves as the committee chair, and file a *program of study* approved by all committee members. The M.S. supervisory committee has overall responsibility for guiding the student toward successful completion of the degree and for examining the student prior to graduation. Each committee member reads the thesis, attends the thesis defense and oral comprehensive exam, and votes to pass or fail the student in their M.S. program.

The M.S. supervisory committee consists of the chair (typically the advisor) and at least two (2) additional members chosen by the student and his or her committee chair. The committee chair must be a tenure-track faculty member in the ECE department at MSU-Bozeman. The other two members can be chosen from the tenure-track and adjunct faculty of the ECE department and allied departments related to the student's research, but the majority (half in the case of 4 members) of the committee must be from the ECE tenure-track faculty. In some cases of collaborative research it might be appropriate for the student to include a member from outside the MSU faculty (an external member of an M.S. committee is approved by the committee chair).

3.2 Program of Study

The *program of study* form must be completed by the student and approved by the supervisory committee and the Graduate School before the end of the student's second semester in the graduate program. Failing to meet this deadline constitutes lack of progress toward the graduate degree and is grounds for probation, suspension of financial support, and possible dismissal from the graduate program. This form lists all courses to be taken by the student for their graduate degree. Students are encouraged to include courses in their program of study from appropriate departments outside of ECE, such as mathematics, physics, and computer science.

For a plan-A M.S. degree, the program of study must include:

- 10 credits of *Master's Thesis* (EELE 590)
  [Note: a student who has taken *Ph.D. Dissertation* (EELE 690) credits may use them in place of EELE 590 if earning a M.S. en route to Ph.D. or if converting from Ph.D. to M.S. status.]
- $\geq$ 20 credits of coursework
  - $\geq$ 10 course credits at 500-600 level
  - $\leq$ 9 credits at 400 level

Further conditions on the distribution of course credits are as follows:

- All courses must be less than 6 years old at the time of graduation.
- ≤ 4 credits *Independent Study* (EELE 592) for plan-A M.S. degree
- ≤ 6 credits *Independent Study* (EELE 592) for plan-B M.S. or M.Eng. degree
- ≤ 10 credits EELE 592 and graduate seminar courses (ENGR 694)
- ≤ 3 credits pass/fail (not counting thesis)
- ≤ 6 credits may be challenged
- No credits of 488, 489, 490, 492, 494, 498, 575, or 589 are allowed

3.3 Timeline

By middle of second semester
Assemble supervisory committee and file *Program of Study* form to the Graduate School for approval (file any necessary changes to program of study before the end of the affected term).

As early as possible
Present a thesis proposal to the supervisory committee (format at discretion of advisor).

In graduation term

- Register for ≥ 3 credits.
- Submit *Application for Advanced Degree* to the Graduate School **(by September 20 for fall, February 5 for spring, and June 10 for summer).**
- Schedule *Comprehensive Oral Examination and Thesis Defense* and deliver advisor-approved thesis to supervisory committee (**2 weeks before exam**).
- Pass *Comprehensive Oral Exam & Thesis Defense* **(≥ 2 weeks before end of term).**
- Make modifications and corrections to thesis as required by your committee (**in time to be approved at the Graduate School at least two weeks before end of term**).
- Department Head approval on committee-approved thesis (≥ 2 weeks before end of term).
- Graduate School approval of department-approved thesis (≥ 2 weeks before end of term).
- Submit CD containing electronic thesis approved by your committee, the ECE Department Head, and the Graduate School to the ECE department (**≥ two weeks before end of term**).
- Submit ECE-approved electronic thesis, *Electronic Thesis/Dissertation Approval Form* signed by all committee members, and *Thesis/Dissertation/Professional Paper Report* signed by the ECE department head, to the Graduate School **(in time to be approved at the Graduate School at least two weeks before end of term**).

Several items must be completed two weeks before the end of the graduation term, but significant delays can occur for each step. For example, it typically takes one to two weeks after the thesis defense for the revised thesis to be approved by the supervisory committee, and additional days are required for thesis approval by the ECE Department Head and the Graduate School. All of this must happen at least 2 weeks before the end of the term, so it is essentially impossible to meet graduation deadlines if the thesis defense is held later than three or four weeks before the end of the term.

3.4 M.S. (plan A) Examinations

There are two major examinations to be completed by a M.S. student. The objectives and procedures for these examinations are described here.

3.4.1 Graduate Study Qualifying Examination

Description:
Each M.S. student must pass the graduate study qualifying examination, a written test of the student's preparation in mathematics and fundamental ECE topics at the undergraduate level. See section 1.7 for details.

Timing:
M.S. students must take the qualifying exam during their first year of registration in the M.S. program. A one-semester delay may be requested by students who enter from non-ECE programs. The exam is offered once each fall and spring, typically in the third week of the term.

3.4.2 Comprehensive Examination and Thesis Defense

The plan-A M.S. degree requires a comprehensive examination and thesis defense as the culminating test of the student's learning and accomplishments. The written portion of this examination is the thesis itself, which must be approved in format and content (including proper grammar and writing style) by the committee. Because it is common for the committee to require thesis editing and modification following the thesis defense, the student must schedule their thesis defense early enough in the graduation term to have sufficient time to make these changes and gain the approval of their committee and the ECE department head before the thesis submission deadline. As an approximate guideline, obtaining final committee and department approval of a successfully defended thesis often takes one-to-two weeks. This time may be shortened by submitting the thesis to the committee only after careful editing by the student and the advisor. The thesis should not be given to the committee members before the advisor has read and approved it for such distribution. Similarly, the advisor's permission must be obtained before a student schedules his or her thesis defense and the advisor may solicit recommendations from the supervisory committee members before authorizing this scheduling.

The oral comprehensive examination includes a public oral presentation by the student of their thesis project, followed by a closed-door period during which the committee members ask questions related to the thesis project and the student's academic background (including courses taken by the student and material expected to be known by a professional at this level in the field). The oral examination and thesis defense are supervised by the advisor. For the student to pass this examination, a majority of the committee members must vote to pass. If a majority votes to fail, the student fails the examination. The examination can be repeated once, no sooner than two months after the failed attempt. A second failure results in suspension from the graduate program. If a thesis requires other than minor revisions that can be completed within the one-week deadline for reporting the outcome of the comprehensive examination and thesis defense, the student should be failed. If the oral comprehensive examination is deemed acceptable, the supervisory committee may choose to forego a second thesis defense presentation or oral examination and simply meet with the student to review the revised thesis.

3.5 Thesis Guidelines

The M.S. thesis is a report of research performed by the student with guidance from their supervisory committee. The thesis topic is approved early in the student's degree program by the committee, and typically arises as part of the advisor's externally funded research program. The project must involve a significant effort by the student and must generate results that are of sufficient quality and significance to be reported in at least one national or international conference presentation or paper (or journal paper). The M.S. thesis does not necessarily need to result in a paper published in the peer-reviewed archival literature, although it is highly desirable that each thesis does at least contribute significantly to such a paper.

All theses at MSU are submitted in electronic form, so the student can use color figures and even multimedia as appropriate. For details on format and submission requirements, the student is referred to the Graduate School (specific format requirements are available online at http://www.montana.edu/etd/ but each student chooses a reference style following the standards of a journal in their field). Each student must also submit an electronic copy of their thesis to the ECE department before graduating.

4. MS without Thesis (Plan B) Requirements and Procedures

A plan-B Master of Science (M.S.) degree in electrical engineering is a practice-oriented degree intended to provide the student advanced education that goes deeper and broader than the undergraduate degree and to provide experience working on a professional engineering project. All plan-B M.S. students must write a professional paper that is approved by their advisor and pass an oral comprehensive examination with their supervisory committee.

4.1 Supervisory Committee

Each plan-B M.S. student must find an appropriate project and advisor and, by the end of their second semester in the graduate program, choose their supervisory committee members (in consultation with their advisor who serves as the committee chair) and file a *program of study* approved by all committee members. The M.S. supervisory committee has overall responsibility for guiding the student toward degree completion and for examining the student prior to graduation. The advisor reads and approves the professional paper, and each committee member attends the comprehensive oral examination and votes to pass or fail the student in their M.S. program.

The M.S. supervisory committee consists of at least three (3) members chosen by the student and his or her committee chair. The committee chair must be a tenure-track faculty member in the ECE department at Montana State University-Bozeman. The other two members can be chosen from the faculty of the ECE department and allied departments. The majority of the committee must be from the ECE tenure-track faculty. In some cases it might be appropriate for the student to include a member from outside the MSU faculty (whose CV must be submitted to the Graduate School).

4.2 Program of Study

The *program of study* form must be completed by the student, approved by the supervisory committee, and submitted to the Graduate School before the end of the second semester of graduate enrollment. Failing to meet this deadline constitutes lack of progress toward the graduate degree and is grounds for probation, suspension of financial support, and possibly dismissal from the graduate program. This form lists all courses to be taken by the student for their graduate degree (except any additional courses required by the committee to correct deficiencies and weaknesses). Students are encouraged to include relevant courses in their program of study from non-ECE departments.

For a plan-B M.S. degree, the program of study must include:

- 3 credits of *Professional Paper/Project* (EELE 575)
- $\geq$ 27 credits of coursework
    - $\geq$ 18 course credits at 500-600 level.
    - $\leq$ 9 credits at the 4xx level.

Further conditions on the distribution of course credits are as follows:

- All courses must be less than 6 years at the time of graduation.
- $\leq$ 6 credits *Independent Study* (EELE 592)
- $\leq$ 10 credits EELE 592 and seminar courses
- $\leq$ 3 credits pass/fail
- $\leq$ 6 credits may be challenged
- No credits of 488, 489, 490, 492, 494, 498, 575, or 589 are allowed

4.3 Timeline

Middle of second semester
Assemble supervisory committee and file *Program of Study* form to the Graduate School for approval (file any necessary changes to program of study before the end of the affected term).

As early as possible
Present professional paper proposal to the advisor (and committee if desired by the advisor).

In graduation term

- Register for ≥ 3 credits.
- Submit *Application for Advanced Degree* to the Graduate School **(by September 20 for fall, February 5 for spring, or June 10 for summer).**
- Schedule *Comprehensive Oral Examination* (**2 weeks before exam**).
- Pass *Comprehensive Oral Exam* **(≥ 2 weeks before end of term).**
- Deliver completed professional paper to advisor for approval (**≥ 1 week before end of term** to allow time for corrections).
- Submit approved professional paper electronically (on CD) to the ECE department (**before receiving grade for EELE 575**).

4.4 M.S. (plan B) Examinations

The plan-B M.S. degree requires a comprehensive oral examination as the culminating test of the student's learning and accomplishments. In contrast with the plan-A examination that focuses heavily on the thesis defense, the plan-B examination focuses exclusively on the content of courses taken by the student and knowledge that should be held by a beginning professional in the field. It is common for the student to present the results of the professional paper publicly, but the paper is not part of the comprehensive examination. Rather, the advisor assigns a letter grade for the paper (i.e., for EELE 575) that is entirely independent of the comprehensive examination results.

The comprehensive oral examination is a closed meeting during which the supervisory committee members ask questions related to the student's coursework (including undergraduate and graduate courses) and material expected to be known by a beginning ECE professional. The examination proceedings are supervised by the advisor. For the student to pass, a majority of the committee members must vote to pass; if a majority of the committee votes to fail, the student fails the examination. The examination can be repeated once, no sooner than two months after the failed attempt. A second failure results in suspension from the ECE graduate program.

4.5 Professional Paper Guidelines

The M.S. plan-B professional paper is a report of work performed by the student at the level of an early-career professional, practicing engineer, with guidance from the advisor. The paper can report on any topic approved by the supervisory committee, but usually covers some focused aspect of a research, design, or educational project. The project must involve a significant effort by the student, but is not as comprehensive as a thesis and does not need to be original research published in the archival literature. It is desirable that a plan-B M.S. project contribute to a conference paper or presentation.

The professional paper must be approved in format and content (including proper grammar and writing style) by the advisor. Students must submit their draft paper early enough to leave time for editing before the end of the term. Plan-B professional papers normally are submitted in electronic form only to the ECE department, so the student and advisor are free to choose a format that is appropriate in the subfield represented by the work (often the format of a journal in the field), without need to follow the Graduate School formatting guidelines. However, in some cases, the advisor may choose to have a student submit their professional paper to the Graduate School for distribution via the electronic thesis web page. In this case, the paper must be formatted in accordance with the thesis requirements published by the Graduate School.

5. Master of Engineering Requirements and Procedures

A Master of Engineering (M.Eng.) degree in electrical engineering is a practice-oriented degree intended to provide the student advanced education that goes deeper and broader than the undergraduate degree, but without a research component. For example, this degree is particularly relevant to engineers employed in industry who desire further training through advanced courses. M.Eng. students are not required to take either a qualifying or comprehensive exam, but instead satisfy degree requirements through coursework exclusively. M.Eng. students are generally not eligible for departmental financial support.

5.1 Supervisory Committee

Each M.Eng. student is advised by the ECE Department Graduate Coordinator. There is no supervisory committee.

5.2 Program of Study

The *program of study* form must be completed by the student and approved by the ECE Graduate Coordinator before the end of the student's second semester in the program. Failure to meet this deadline constitutes lack of progress toward the degree and is grounds for probation, suspension of financial support, and possibly dismissal from the graduate program. This form lists all courses to be taken by the student for their graduate degree (except any additional courses required by the supervisory committee to correct deficiencies and weaknesses). Students are encouraged to include courses in their program of study from appropriate departments outside of ECE, such as mathematics, physics, and computer science.

A M.Eng. program of study must include:

- 30 credits of courses selected either from the M.Eng. approved course list or by petition.
    - $\geq$ 18 course credits at 5xx-6xx level.
    - $\leq$ 12 credits at 4xx level).

Further conditions on the distribution of course credits are as follows:

- $\leq$ 9 credits can be reserved for graduate credit during an undergraduate program (these credits do not count toward the undergraduate degree).
- $\leq$ 9 credits of non-ECE classes are allowed.
- All courses must be less than 6 years old at the time of graduation.
- $\leq$ 6 credits *Independent Study* (EELE 592).
- $\leq$ 10 credits EELE 592 and seminar courses.
- $\leq$ 3 credits pass/fail.
- $\leq$ 6 credits may be challenged.
- No credits of 488, 489, 490, 492, 494, 498, 575, or 589 are allowed.

5.3 Approved M.Eng. Courses

Pre-approved courses offered by the ECE department are:

- All 400-level EELE courses except for 487, 488, 489, and 49x.
- all 500-level EELE courses except for 589 and 590 (for dual-listed courses offered with both 4xx and 5xx versions, graduate students should take the 5xx version).

Pre-approved courses offered by other departments at MSU are:

All 400-level CSCI courses except those numbered 480 and above
All 500-level CSCI courses except those numbered 580 and above

M 441	Numerical Linear Algebra & Optimization
M 442	Numerical Solutions to Differential Equations
M 450	Applied Mathematics I
M 451	Applied Mathematics II
M 472	Introduction to Complex Analysis
M 503	Advanced Linear Algebra
M 509	Stochastic Processes
M 544	Partial Differential Equations I
M 545	Partial Differential Equations II
M 551	Complex Analysis
M 560	Methods of Applied Mathematics I
M 561	Methods of Applied Mathematics II
PHSX 423	Electricity and Magnetism I
PHSX 425	Electricity and Magnetism II
PHSX 427	Advanced Optics
PHSX 437	Laser Applications
PHSX 441	Solid State Physics
PHSX 442	Novel Materials for Physics and Engineering
PHSX 444	Advanced Physics Lab
PHSX 446	Thermodynamics and Statistical Physics
PHSX 461	Quantum Mechanics I
PHSX 462	Quantum Mechanics II
PHSX 516	Experimental Physics
PHSX 531	Nonlinear Optics and Laser Spectroscopy
PHSX 535	Statistical Mechanics
PHSX 544	Condensed Matter Physics I
PHSX 545	Condensed Matter Physics II
PHSX 566	Mathematical Physics I
PHSX 567	Mathematical Physics II
BMGT 505	The Strategic Management of Technological Innovation

Student wishing to take a course not on this list of approved courses may submit a petition that lists the course number, title, and course description, along with a statement on how this course will benefit the student's program of study. The petition should be submitted to the graduate coordinator.

5.4 Timeline

On admission
Meet with Graduate Coordinator and file *Program of Study* form to the Graduate School for approval (file any necessary changes to program of study before the end of the affected term).

In graduation term

- Register for ≥ 3 credits.
- Submit *Application for Advanced Degree* to the Graduate School **(by September 20 for fall, February 5 for spring, or June 10 for summer).**

5.5 M.Eng. Examinations

The M.Eng. degree is earned exclusively by satisfying the requisite coursework with acceptable grades.

6. Research Areas

The ECE faculty is dedicated to maintaining a vibrant research program that provides opportunities for graduate and undergraduate students to participate in cutting-edge engineering and applied science, often in interdisciplinary endeavors. This chapter describes these activities in terms of broad research areas of national emphasis. A curriculum-oriented description of research activities and relevant classes is provided in chapter 7.

6.1 Current Activities

In broad terms, the current ECE research activities can be described as follows:

Communication Systems (J. Becker, K. Repasky, R. Wolff, J. Shaw)
Wireless communication systems, ad-hoc networks, fiber optic communication components and systems, micro-machined mm-wave components, antennas, and atmospheric propagation.

Computation Systems and Signal Processing (B. LaMeres, R. Maher, R. Snider, N. Nategh)
Biologically inspired signal processing, DSP hardware, novel computational techniques using FPGAs, Micro-controllers and embedded systems, digital signal processing, optimal filtering, spectral envelope estimation, compression, audio and acoustical signal processing, and acoustic animal detection and recognition.

Energy and Materials (H. Gao, H. Nehrir, S. Shaw)
Fuel cells, fuel cell materials, fuel cell modeling and control; renewable resource and fuel cell distributed generation systems; fuzzy logic and neural network applications to power system control; load management; reduced-component power electronic design and motor drives.

Micro-Electro-Mechanical Systems (MEMS) (J. Becker, D. Dickensheets, W. Nakagawa, T. Kaiser)
Micro-machined components for millimeter-wavelength systems; MEMS tip-tilt and variable-focus mirrors and Micro-Optical-Electro-Mechanical Systems (MOEMS) components in optical imaging and spectroscopic systems; MEMS capacitive and inductive sensors.

Optical Systems & Photonics (D. Dickensheets, W. Nakagawa, K. Repasky, J. Shaw, R. Wolff)
Micro-Optical-Electro-Mechanical Systems (MOEMS), micro-machined mirrors and applications in confocal microscopes, spectrometers, and sensors; optical remote sensing systems and applications; lidar development and applications to measuring atmospheric aerosols, clouds, and gases; radiometric and polarimetric imaging system development and calibration; optical sensors for detecting explosives and biological species; optical communication components, systems, and networks.

Sensors and Systems (T. Kaiser, R. Maher, K. Repasky, J. Shaw, S. Shaw)
MEMS sensors and components; micro-machined sensors; lidars, laser sensors, radiometric and polarimetric imagers (see Optics and photonics section above); electronic sensors and systems for data acquisition and optical system control; acoustic and audio sensing of environmental noise and wildlife.

6.2 Interdisciplinary Collaboration Opportunities

There is significant opportunity for graduate students to work on collaborative projects with ECE faculty and a variety of MSU research centers or departments. Students interested in working on collaborative projects are encouraged to contact faculty with relevant research interests. Current or recent projects have involved ECE faculty working with the following MSU organizations:

- Center for Biofilm Engineering (CBE) – www.biofilm.montana.edu
- Center for Zero Emissions Research and Technology (ZERT) – www.montana.edu/zert
- Dep't of Land Resources & Environmental Sciences – http://landresources.montana.edu
- Montana Institute on Ecosystems - http://montanaioe.org/
- Department of Chemical and Biological Engineering – www.chbe.montana.edu
- Department of Civil Engineering – www.coe.montana.edu/ce
- Department of Computer Science – www.cs.montana.edu
- Department of Earth Sciences – www.montana.edu/wwwes
- Department of Mechanical & Industrial Eng. – www.coe.montana.edu/mie
- Department of Mathematical Sciences – www.math.montana.edu
- Department of Physics – www.physics.montana.edu
- Energy Research Institute – www.montana.edu/energy
- Montana Space Grant Consortium (MSGC) http://spacegrant.montana.edu
- Optical Technology Center (OpTeC) – www.optec.montana.edu
- Space Science and Engineering Laboratory (SSEL) – http://ssel.montana.edu
- Spectrum Lab – www.spectrum.montana.edu
- Western Transportation Institute (WTI) – http://www.wti.montana.edu/

7. Curriculum Areas

ECE graduate students consult with their advisor and supervisory committee to design a unique curriculum for their degree (within the prescribed requirements). Students can use the following lists of courses often taken by students in different curricular areas to help identify areas that match their interests. These lists are not exclusive or required, but only offered as guidelines.

7.1 MEMS and Electronics

1) MEMS

EELE 407 Introduction to Microfabrication
EELE 409 EE Material Science
EELE 414 Introduction to VLSI Design
EELE 415 Analog Integrated Circuit Design
EELE 503 Advanced Electronics
EELE 505 MEMS Sensors and Actuators

EGEN 415 Advanced Mechanics of Solids
EGEN 435 Fluid Dynamics
EM 510 Elastic & Inelastic Analysis I
EM 525 Continuum Mechanics
EM 526 Advanced Continuum Mechanics

EM 560 Finite Element Analysis in Engineering
M 442 Numerical Solution of Differential Equations

2) Electronics

EELE 321* Intro. to Feedback Controls
EELE 422 Intro. to Modern Control
EELE 407 Intro. to Microfabrication
EELE 409 Material Science
EELE 411 Advanced Analog Electronics
EELE 414 Intro. to VLSI Design
EELE 503 Advanced Analog Circuit Design

M 442 Numerical Solution of Differential Equations

* Deficiency class taken if students have not taken comparable classes previously.

7.2 Optics and Electromagnetics

1) Optics and Photonics

EELE 407 Introduction to Microfabrication
EELE 408 Photovoltaic Systems
EELE 432 Applied Electromagnetics
EELE 482 Electro-Optical Systems
EELE 505 MEMS Sensors and Actuators
EELE 533 Antenna Engineering
EELE 538 Advanced Topics in Electromagnetics and Optics
EELE 581 Fourier Optics & Imaging Theory
EELE 582 Optical Design
EELE 583 Remote Sensing Systems
EELE 584 Laser Engineering

PHSX 461 Quantum Mechanics I
PHSX 462 Quantum Mechanics II
PHSX 427 Advanced Optics
PHSX 437 Laser Applications
PHSX 506 Quantum Mechanics I
PHSX 507 Quantum Mechanics II
PHSX 516 Experimental Physics
PHSX 531 Nonlinear Optics and Laser Spectroscopy

M 441 Numerical Linear Algebra & Optimization
M 442 Numerical Solution of Differential Equations
M 450 Applied Mathematics I
M 451 Applied Mathematics II
STAT 401 Applied Methods in Statistics
STAT 410 Methods for Data Analysis I
STAT 412 Methods for Data Analysis II

2) Electromagnetics

EELE 407 Intro. to Microfabrication
EELE 432 Applied Electromagnetics
EELE 433 Planar Microwave Circuit Design
EELE 482 Electro-Optical Systems
EELE 503 Advanced Analog Circuit Design
EELE 505 MEMS Sensors and Actuators
EELE 533 Antenna Engineering
EELE 538 Advanced Topics in Electromagnetics and Optics
EELE 583 Remote Sensing Systems
EELE 584 Laser Engineering

M 442 Numerical Solution of Differential Equations
M 449 Intro. to Complex Analysis
M 450 Applied Mathematics I
M 451 Applied Mathematics II

7.3 Communications, Signals, and Controls

1) Communications

EELE 432 Applied Electromagnetics
EELE 433 Planar Microwave Circuit Design
EELE 445 Telecommunication Systems
EELE 446 Telecommunication Lab
EELE 447 Mobile Wireless Communications
EELE 482 Electro-Optical Systems
EELE 483 Fiber and Optical Communications
EELE 533 Antenna Engineering
EELE 541 Advanced Communication Theory
EELE 542 Information Coding & System Design
EELE 543 Advanced Telecommunication Systems
EELE 547 Adhoc Wireless Sensor Networks
EELE 548 Advanced Topics in Communication Systems
EELE 583 Remote Sensing Systems
EELE 584 Laser Engineering

CSCI 466 Networks
CSCI 520 Parallel and Distributed Computing
CSCI 566 Advanced Networking

EIND 422 Introduction to Simulation

M 442 Numerical Solution of Differential Equations

STAT 401 Applied Methods in Statistics
STAT 509 Stochastic Processes

2) Signals

EELE 422 Modern Controls
EELE 477 Digital Signal Processing
EELE 517 Acoustics & Audio Engineering
EELE 577 Advanced Digital Signal Processing
EELE 578 Speech Signal Processing
EELE 525 System Identification
EELE 526 Sequential State Estimation
EELE 528 Advanced Topics – Controls & Signals

M 441 Numerical Linear Algebra & Optimization
M 454 Intro. to Dynamical Systems I

STAT 401 Applied Methods in Statistics

CSCI 442 Computer Vision: Robot Vision
CSCI 446 Artificial Intelligence
CSCI 541 Computer Graphics

3) Controls

EELE 321* Intro. to Controls
EELE 422 Intro. to Modern Controls
EELE 477 Digital Signal Processing
EELE 522 Adaptive Control
EELE 525 System Identification
EELE 526 Sequential State Estimation
EELE 528 Advanced Topics – Controls & Signals
EELE 577 Advanced Digital Signal Processing

M 333* Linear Algebra
M 441 Numerical Linear Algebra & Optimization
M 454 Intro. to Dynamical Systems I
M 455 Intro. to Dynamical Systems II

STAT 401 Applied Methods in Statistics

* Graduate students take these deficiency classes if they do not have comparable background.

7.4 Computer Engineering

EELE 465 Microcontroller Applications
EELE 466 Computer Architecture and System Organization
EELE 467 Advanced Embedded Systems Lab
EELE 475 Microprocessor Hardware and Software Engineering
EELE 477 Digital Signal Processing
EELE 561 Digital System Design
EELE 564 Advanced Computer Architecture
EELE 565 Parallel and Associative Processors
EELE 577 Advanced Digital Signal Processing

CSCI 441 Computer Graphics
CSCI 442 Computer Vision: Robot Vision
CSCI 446 Artificial Intelligence
CSCI 445 Embedded Systems: Robotics
CSCI 547 Machine Learning
CSCI 520 Parallel and Distributed Computing

STAT 401 Applied Methods in Statistics

7.5 Power and Power Electronics

EELE 451 Power Electronics
EELE 454 Electric Power Systems
EELE 455 Alternative Energy Power Generation
EELE 552 Advanced Power System Analysis & Control
EELE 555 Alternative Energy Distributed Generation Systems
EELE 556 Advanced Power Electronics
EELE 558 Advanced Topics – Electrical Power

M 454 Dynamical Systems I
M 455 Dynamical Systems II

8. ECE Courses Available for Graduate Credit

Graduate students take courses from the following list, in addition to relevant 400- and 500-level courses in mathematics, physics, computer science, and other related departments.

EELE 407 Intro. to Microfabrication
EELE 408 Photovoltaics
EELE 409 Material Science
EELE 411 Advanced Analog Electronics
EELE 414 Introduction to VLSI Design
EELE 422 Intro. to Modern Control
EELE 432 Applied Electromagnetics

EELE 433 Planar Microwave Circuit Design
EELE 445 Telecommunications Systems
EELE 447 Mobile Wireless Communications
EELE 451 Power Electronics
EELE 454 Electric Power Systems
EELE 461 Digital System Design
EELE 465 Microcontroller Applications
EELE 466 Computer Architecture and System Organization
EELE 475 Hardware and Software Engineering for Embedded Systems
EELE 477 Digital Signal Processing
EELE 482 Electro-Optical Systems
EELE 483 Fiber and Optical Communications
EELE 491 Special Topics
EELE 503 Advanced Analog Circuit Design
EELE 505 MEMS Sensors and Actuators
EELE 517 Acoustics & Audio Engineering
EELE 522 Adaptive Control
EELE 525 System Identification
EELE 526 Sequential State Estimation
EELE 528 Advanced Topics – Controls & Signals
EELE 533 Antenna Engineering
EELE 538 Advanced Topics in Electromagnetics and Optics
EELE 541 Advanced Communication Theory
EELE 543 Advanced Telecommunications Systems
EELE 547 Adhoc Wireless Sensor Networks
EELE 548 Advanced Topics in Communications Systems
EELE 552 Advanced Power Systems Analysis & Control
EELE 555 Alternative Energy Distributed Generation Systems
EELE 556 Advanced Power Electronics
EELE 558 Advanced Topics – Electrical Power
EELE 561 Digital System Design
EELE 565 Parallel Processing
EELE 575 Research or Professional Paper/Project (M.S. plan-B students only)
EELE 577 Advanced Digital Signal Processing
EELE 578 Speech Signal Processing
EELE 581 Fourier Optics and Imaging Theory
EELE 582 Optical Design
EELE 583 Remote Sensing Systems
EELE 584 Laser Engineering
EELE 590 Master's Thesis
EELE 591 Special Topics
EELE 592 Independent Study
EELE 690 Doctoral Thesis

9. Faculty

Tenure-Track Faculty

James Becker, Associate Professor
Ph.D. Electrical Engineering, University of Michigan
M.S. Electrical Engineering, Colorado State University
B.S. Ceramic Engineering, University of Illinois, Urbana-Champaign
Research interests: Silicon micro-machining for millimeter-wave applications.
Contact: 535 Cobleigh Hall, 406-994-5988, jbecker@ece.montana.edu

David Dickensheets, Professor
Ph.D. Electrical Engineering, Stanford University
M.S. Electrical Engineering, University of Washington
B.S. Electrical Engineering, University of Colorado
Research interests: Optical microscopy and tissue imaging, silicon micro-machining and micro-opto-electro-mechanical systems (MOEMS), miniature imaging and spectroscopy instruments.
Contact: 530 Cobleigh Hall, 406-994-7874, davidd@ece.montana.edu

Hongwei Gao, Associate Professor
Ph.D. Electrical Engineering, Texas A&M University
M.S. Electrical Engineering, Tsinghua University
B.S. Electrical Engineering, Tsinghua University
Research interests: Electric motor drives, power electronics, electric vehicles, renewable energy.
Contact: 635 Cobleigh Hall, 406-994-5973, hgao@ece.montana.edu

Todd Kaiser, Associate Professor
Ph.D. Electrical Engineering, Georgia Institute of Technology
M.S. Physics, Oregon State University
B.S. Physics, Montana State University
Research interests: Micro Electro-Mechanical Systems (MEMS), inertial sensors and fiber optic systems.
Contact: 531 Cobleigh Hall, 406-994-7276, tjkaiser@ece.montana.edu

Brock LaMeres, Assistant Professor
Ph.D. Electrical Engineering, University of Colorado – Boulder
M.S. Electrical Engineering, University of Colorado – Colorado Springs
B.S. Electrical Engineering, Montana State University
Research interests: High-speed digital design, programmable logic, interconnect systems, microprocessor & microcontroller based systems.
Contact: 533 Cobleigh Hall, 406-994-5987, lameres@ece.montana.edu

Robert Maher, Professor and Department Head
Ph.D. Electrical Engineering, University of Illinois - Urbana
M.S. Electrical Engineering, University of Wisconsin - Madison
B.S. Electrical Engineering, Washington University
Research interests: digital signal processing, audio engineering, and acoustics
Contact: 610 Cobleigh Hall, 406-994-7759, rmaher@ece.montana.edu

Wataru Nakagawa, Assistant Professor
Ph.D. Electrical and Computer Engineering, University of California-San Diego
M.S. Electrical and Computer Engineering, University of California-San Diego
B.S. Physics, Stanford University
B.A. Urban Studies, Stanford University
Research interests: Near-field optical interactions in nanostructures, novel photonic devices based on nanostructures.
Contact: 529 Cobleigh Hall, 406-994-5956, wataru.nakagawa@ece.montana.edu

Neda Nategh, Assistant Professor
Ph.D. Electrical Engineering, Stanford University
M.S. Statistics, Stanford University
M.S. Electrical Engineering, Stanford University
B.S. Electrical Engineering, Sharif University of Technology
Research interests: statistical signal processing; statistical learning, image processing; (biologically inspired) machine vision, development and application of statistics; dynamical systems theory; information theory; machine learning; and optimization techniques to study neural data; computational neuroscience.

M. Hashem Nehrir, Professor
Ph.D. Electrical Engineering, Oregon State University
M.S. Electrical Engineering, Oregon State University
B.S. Electrical Engineering, Oregon State University
Research interests: Electric power systems, electric machines, alternative energy.
Contact: 626 Cobleigh Hall, 406-994-4980, hashemn@ece.montana.edu

Kevin Repasky, Associate Professor
Ph.D. Physics, Montana State University
B.S. Mechanical Engineering, Youngstown State University
Research interests: laser physics and engineering, photonics, optical communications, optical remote sensing.
Contact: 637 Cobleigh Hall, 406-994-6082, repasky@ece.montana.edu

Joseph Shaw, Professor and Director of the Optical Technology Center
Ph.D. Optical Sciences, University of Arizona
M.S. Optical Sciences, University of Arizona
M.S. Electrical Engineering, University of Utah
B.S. Electrical Engineering, University of Alaska
Research interests: Development and application of optical remote sensing systems, including radiometers, polarimeters, and lidars; photography and science of optical phenomena in nature; atmospheric propagation of electromagnetic waves.
Contact: 518 Cobleigh Hall, 406-994-7261, jshaw@ece.montana.edu

Steven Shaw, Professor
Ph.D. Electrical Engineering, Massachusetts Institute of Technology
E.E., Massachusetts Institute of Technology
M. Eng. Electrical Engineering, Massachusetts Institute of Technology
S.B. Electrical Engineering & Computer Science, Massachusetts Institute of Technology
Research interests: System identification, modeling, control and instrumentation.
Contact: 532 Cobleigh Hall, 406-994-5982, sshaw@ece.montana.edu

Ross Snider, Associate Professor
Post-Doctoral Research, Johns Hopkins University
Ph.D. Electrical Engineering, Vanderbilt University
M.S. Electrical Engineering, Michigan State University
B.S. Engineering, Walla Walla College
Research interests: Signal processing, speech recognition, real-time systems, auditory and visual neuroscience.
Contact: 538 Cobleigh Hall, 406-994-1645, rksnider@ece.montana.edu

Richard Wolff, Professor and Gilhousen Telecommunications Chair
Ph.D. Physics, Columbia University (experimental X-ray astronomy)
B.S. Physics, University of California – Berkeley
Research interests: Optical networks, packet switching, wireless systems, satellite communications, ad hoc networks, telematics.
Contact: 509 Cobleigh Hall, 406-994-7172, rwolff@ece.montana.edu

Research and Adjunct Faculty

Robert Gunderson, Adjunct Professor
Ph.D. Electrical Engineering, University of Alabama
M.S. Electrical Engineering, University of Alabama
B.S. Physics, Montana State University
Professional interests: Controls, robotics systems, intelligent systems, and pattern recognition.
Contact: 536 Cobleigh Hall, 406-994-5989, rgunderson@ece.montana.edu

Yikun Huang, Associate Research Professor
Ph.D. Electrical Engineering, University of Illinois – Chicago
M.S. Optics, Institute of Optics and Fine Mechanics, Chinese Academy of Sciences
B.S. Physics, Peking University
Professional interests: Smart antenna/MIMO systems, array signal processing, neuronal signal identification and discrimination, wireless/ad hoc communications.
Contact: 617 Cobleigh Hall, 406-994-5983, yhuang@ece.montana.edu

Randy Larimer, Adjunct Instructor and Deputy Director of the Montana Space Grant Consortium
M.S. Electrical Engineering, Montana State University
B.S. Electrical Engineering, Montana State University
Professional interests: embedded systems, microprocessors, computer engineering, digital systems.
Contact: 634 Cobleigh Hall, 406-994-5970, rlarimer@ece.montana.edu

Andy Olson, Adjunct Instructor (RF Engineer, Spectrum Lab)
B.S. Electrical Engineering, Montana State University
Professional interests: Communications electronics, active and passive microwave circuits.
Contact: 631 Cobleigh Hall, 406-994-5967, andyo@ece.montana.edu

Recent Emeritus Faculty

Frederick M. Cady, Professor Emeritus
Ph.D. Electrical Engineering, University of Canterbury, New Zealand
M.S. Electrical Engineering, California Institute of Technology
B.S. Electrical Engineering, Pennsylvania State University
Research interests: Microcomputers, image processing, electro-optic systems.

Victor Gerez, Professor Emeritus
Ph.D. Engineering, University of California, Berkeley
M.S. Electrical Engineering, University of California, Berkeley
B.S. Electrical Engineering, National University of Mexico
Research interests: Power systems, energy conversion, alternate energy.

Bruce McLeod, Professor Emeritus
Ph.D. Electrical Engineering, University of Colorado - Boulder
M.S. Electrical Engineering, University of Colorado – Boulder
B.S. Electrical Engineering, Colorado State University
Research interests: Electromagnetic fields in biological materials.

James Peterson, Professor (retired department head)
Ph.D. Electrical Engineering, Iowa State University
M.S. Electrical Engineering, University of Idaho
B.S. Electrical Engineering, University of Idaho
Research interests: Digital filtering, signal processing, estimation and control

Don Pierre, Professor Emeritus
Ph.D. Electrical Engineering, University of Wisconsin - Madison
M.S. Electrical Engineering, University of Southern California
B.S. Electrical Engineering, University of Illinois-Urbana
Research interests: control systems

10. Graduate Program Forms, Links, and Resources

The primary resource for graduate program information is the webpage of the MSU Graduate School: www.montana.edu/gradschool.

The online graduate school application is here: http://www.montana.edu/gradschool/apply.html

Forms are available online at http://www.montana.edu/gradschool/forms.html

Here is a description of some of the more commonly used forms:

Program of Study & Committee Form -	Defines your advisor, committee, & classes
Program Change -	For changes in your original program of study
Committee Revision Form -	For changing a member of your committee
Application for Advanced Degree -	Submit in semester of intended graduation
Application for Change in Graduate Status -	Can ONLY be used to go from PhD to MS
Electronic Thesis & Dissertation approval form –	Final approval of thesis or dissertation
Petition to Reserve/Register for Credits -	Allows undergraduates with GPA > 3.25 to take graduate classes.

Thesis and dissertation style guide	www.montana.edu/etd
Electronic Theses & Dissertations	www.montana.edu/etd
Free writing tutoring services for graduate students	http://www.montana.edu/gradwriting/
Graduate student professional development (seminars, teaching and learning, etc.):	http://www.montana.edu/gradschool/seminar.html
International Programs Office	http://www.montana.edu/international/

Other useful links:

Montana State University (MSU)	www.montana.edu
MSU College of Engineering	www.coe.montana.edu
ECE Department	www.coe.montana.edu/ee
ECE Graduate Program Information	www.coe.montana.edu/ee/research/eegrad1.htm
ECE Faculty information	www.coe.montana.edu/ee/faculty.htm