MISSOURI S&T™ | Nuclear Engineering and Radiation Science

Graduate Student Handbook

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1. INTRODUCTION

1.1. WELCOME

Welcome to the Nuclear Engineering Program at Missouri University of Science and Technology. The purpose of this document is to familiarize incoming graduate students with the procedures and policies, and to provide information that will be useful during your time as a graduate student. It is not intended to replace procedures or regulations of the Graduate School but to supplement those with additional details, especially regarding specific requirements in the Nuclear Engineering Program.

The Nuclear Engineering (NE) program is offered under the department of mining and nuclear engineering. The primary mission of the NE program is to provide an outstanding and comprehensive education to tomorrow's leaders in nuclear science and technology. The NE program provides well-educated professionals and leaders to Missouri and the nation, in the commercial nuclear industry, national laboratories, and the nation's defense and federal agencies. Nuclear Engineering is a strong and growing engineering program administered by highly motivated and active nuclear engineering faculty; first accredited in 1960, it is one of the earliest ABET accredited undergraduate programs in the nation and is the only B.S. Nuclear Engineering degree program accredited in the state of Missouri.

1.2. EDUCATIONAL OBJECTIVES

Program Educational Objectives:

Students in Nuclear Engineering MS and PhD programs will:

1. Demonstrate knowledge of nuclear engineering and related technologies;
2. Communicate effectively about their field of study; and
3. Use logical, creative, and collaborative approaches to address nuclear engineering problems.

Student Outcomes:

At the end of their degree program, students in the Nuclear Engineering and PhD Programs will:

1. Identify engineering problems and evaluate the relevant literature to understand how that problem integrates with their professional field as well as other disciplines.
2. Understand the wider context of research, especially with regards to public health and safety, cultural, and economic factors.
3. Write effective technical reports and publications suitable for a range of audiences.
4. Prepare and deliver presentations about technical subjects suitable for a range of audiences.
5. Develop a sound research plan informed by previous work in the field that incorporates innovative approaches to address engineering problems.
6. Apply the principles of science, mathematics, and engineering design to produce solutions to complex problems that meet specific needs and satisfy applicable constraints and professional standards.

7. Analyze and interpret experimental data, simulation results, and other information, draw logical conclusions, and apply those conclusions to their own engineering work.
8. Function effectively on a team to establish goals, plan tasks, and meet objectives.

1.3. RESEARCH LABORATORIES AND FACILITIES

Missouri S&T Reactor (MSTR)

The Missouri S&T Reactor (MSTR) is located on the Missouri University of Science and Technology campus in Rolla, Missouri. MSTR provides facilities for experimental research, undergraduate training, and learning about reactor physics and other aspects of nuclear engineering. It is a 200 kW pool-type reactor, and is integral to the education of Nuclear Engineering students through hands-on laboratory activities. The reactor was initially licensed in 1961, and was converted from high-enriched uranium (HEU) to low-enriched uranium (LEU) in 1992.

Recently MSTR has gone through a number of changes. A new active cooling system capable of removing up to 400 kW of heat was installed using funding from the Department of Energy in 2013. In 2014 new digital control room systems were installed, replacing the original systems from 1961 and allowing MSTR to serve as a testbed for new digital reactor control technologies. A distance education system, also installed in 2014, allows our faculty and staff to provide online training through distance education for students around the world. Additional modifications are planned over the next several years, including the installation of new digital recording systems to replace paper records.

Research facilities, experimental capabilities and services available at the reactor include:

- A neutron beam port for neutron radiography, tomography and ex-core neutron irradiations
- Thermal column for experiments involving thermal neutrons
- Pneumatic transfer tubes for in-core irradiation experiments and Neutron Activation Analysis (NAA)
- Isotope production elements and void tubes for in-core irradiations
- Internet accessible hot cell facility for high-activity sample irradiation and counting
- Subcritical assembly for teaching the fundamentals for reactor physics
- Gamma spectroscopy systems equipped with NaI and High Purity Germanium (HPGe) detectors
- Liquid scintillation counter for alpha and beta spectroscopy
- State-of-the-art distance education system for broadcasting reactor labs to outside universities and organizations

Advanced Radiography and Tomography Laboratory

Radiation imaging has been the most successful and useful method of early cancer detection as well as a highly helpful nondestructive testing method for various industrial applications. In the ARTLAB, we are developing innovative radiation imaging systems for medical and industrial

purposes. We develop and utilize a wide range of new tools, from x-ray sources for radiation imaging to sophisticated algorithms for image processing and computed tomography (CT) reconstruction. One such example is the ongoing project of developing a stationary CT for real-time 4D imaging that will be useful both in medicine and industry. For the stationary CT, a new type of x-ray tubes for fast imaging is under development. Also, we develop machine learning algorithms for radiation image analysis and automatic radioisotope detection for homeland security and defense applications. The lab is equipped with a homemade benchtop 3D CT, a clean room for x-ray tube experiments and a high-performance computer server with COMSOL software for simulation studies.

D-D Neutron Generator Laboratory

The D-D generator uses Deuterium gas and a microwave to generate plasma as an ion source to induce nuclear fusion. This results in a relatively high-flux source of fast and epithermal neutrons useful for prompt gamma neutron activation analysis, neutron activation analysis, and radiography. Using Deuterium rather than radioactive Tritium, as well as an "open-vacuum" construction, allows the system to be easily reconfigured for experiments.

Thermal Hydraulics Experiment, Modeling, and Engineering Simulation (THEMES) Laboratory

The Thermal Hydraulic Experiment, Modeling, and Engineering Simulation (THEMES) Laboratory is designed as a modular, multipurpose facility capable of supporting a wide variety of multiphase flow experiments, simulations, and modeling efforts. The central feature of the THEMES Laboratory is a modular test facility designed to support up to six concurrent experiments by effectively utilizing existing infrastructure. This allows for rapid deployment of experiments, lets projects to progress rapidly to the construction and testing phases, and reduces the cost to the sponsor. A 30 hp pump provides up to 1000 gpm of water flow at 90 ft of head, while a 50 hp compressor provides up to 270 acfm of compressed air at a pressure of 200 psi. Flow is measured using pressure transducers, rotameters, a laminar flow element, a vortex flow meter, a magnetic flow meter, and other state-of-the-art instruments. Robust four-sensor electrical conductivity probes for multiphase flow measurements are constructed and characterized in-house, with unique software for enhancing data processing performance.

Vacuum Technology and X-Ray Generation Laboratory

Located in Fulton 213 this lab has facilities to produce and work with vacuum technology up to 10^{-9} Torr. The equipment includes roughing mechanical pumps, ion pumps, turbo pumps, glass vacuum chambers, steel vacuum chambers with programmable ramp-heating capabilities, Residual Gas Analyzer-RGA200, and a variety of pressure gauges, ion guns, and radiation detectors and other measurement equipment. Total area is 561 sq ft.

Nanotechnology, Nuclear Forensics and Radiochemistry Laboratory

The Radiochemistry and Nanotechnology Laboratory is located in Fulton 218 and houses a fume hood with wet chemistry capabilities, a two seat glove box, chemical waste disposal, safes for radioactive materials, UV-Vis Spectrophotometer, analytical balance, centrifuges, vacuum filtration and drying system, furnace, stereo microscope, ultrasonicators, with a total area of 466 sq. ft.

Nuclear Materials Laboratory

The Nuclear Engineering department is home to two laboratories with specialized equipment for characterizing the effects of radiation on solids at the atomic and microscopic scales. Equipment available includes a Confocal Raman Microscope, a Positron Annihilation Lifetime Spectrometer, a Modulated Photothermal Radiometer, a Three-Omega system configured for thermal diffusivity measurements and a Four-Terminal Resistivity Station. The facilities of the campus Materials Research Center are also available for nuclear materials related research. These facilities include state-of-the-art Scanning and Transmission Electron Microscopes, X-ray Diffractometers, a Nanoindenter, Atomic Force Microscope and X-Ray Photoelectron Spectrometer among other tools. Ample opportunities exist for Nuclear Engineering students to collaborate with students and researchers in the campus Materials Science and Engineering Department.

Radiation Measurements and Spectroscopy Laboratory

RMSL is a teaching lab mainly for education and training of undergraduate nuclear engineering students. Three identical workstations for alpha particle, beta particle, and gamma-ray spectroscopy can provide "hands-on" training in radiation detection and measurement for 18 students at a time. The five internet-accessible digital signal analyzers allow 50 remote users to participate in nuclear spectroscopy and measurement and collection of spectra data via an internet connection at any given time. When the RMSL is not in use for education or training, it is open for faculty and graduate students to conduct research. The lab was significantly renovated with support from DOE and is equipped with state-of-the-art radiation detectors and signal processing systems.

2. ADMISSIONS REQUIREMENTS

In addition to the requirements listed by Missouri S&T for all graduate programs, NERS requires:

- A BS in Nuclear Engineering or a related discipline
- A minimum of 300 composite score on the GRE, and a minimum Quantitative score of 150

Alternatively, students who have completed the Nuclear Nonproliferation certificate may be admitted to the MS program.

An applicant to the nuclear engineering graduate program may have GRE requirements waived if any of the following conditions is met:

1. The applicant's Degree of Record is from Missouri S&T, or
2. The applicant has a nuclear engineering graduate certificate from Missouri S&T, or
3. The applicant's Degree of Record is from an institution ranked in the top 250 of the most current QS World University Rankings, or
4. The applicant's Degree of Record is from an institution with English as the instruction language and ranked in the top 10 of its home country, or
5. The applicant
    i. has Degree of Record from an institution ranked in the top 5 of its home country, and
    ii. has a GPA greater or equal to 3.5 or its equivalent as evaluated by a credential evaluation agency with NACES membership (e.g. WES), and
    iii. has studied English language immersively for at least 1 year or studied abroad for at least one year at an institution with English as its instruction language. The proof of such study must be provided as part of the graduate program application package.

3. GETTING STARTED

3.1. ARRIVAL

On arrival, visit the main office to request a desk assignment. You can request keys for your office. Laboratory keys will be issued, if needed, by the faculty member responsible for the laboratory. A student's main task during the first few days on campus is to become familiar with the campus and surrounding area. The more familiar a student is with the area, the better they will be able to make use of the resources available for meeting their academic milestones. Areas of interest may be computer resources, the Curtis Laws Wilson Library, etc.

The next major task is to select courses and register. This can be complex, and there are several considerations that must be addressed.

- Courses should be consistent with your area of study and degree objectives
- Courses should satisfy graduation requirements
- Students should have sufficient background for more advanced courses
- Courses should avoid duplicating material that has already been studied

Students should discuss the available courses with their advisor, who will review the selections and provide final approval. If an advisor has not yet been selected, the Graduate Coordinator will provide counseling as needed until an appropriate advisor has been selected.

A normal, full-time course load for graduate students is 9-12 credits per semester of both coursework and research. The currently available courses are listed in Joe'SS (https://joess.mst.edu) under 'Schedule of Classes'. The complete list of courses is available under 'Browse Course Catalog'. Textbooks for your courses can be found at the S&T bookstore, in the first floor of Havener Center. Required graduate forms can be found at: https://grad.mst.edu/currentstudents/forms/. Other important forms can be found at: http://registrar.mst.edu/forms/.

Before registering, students with assistantships or department fellowships can obtain specifics regarding their employment and payment from the Nuclear Engineering Main Office (Fulton Hall 222). If the student has any questions regarding employment conditions, they should see their advisor immediately. Teaching assistants will be assigned courses the week before the semester begins. All teaching assistants should meet with the professor to whom the course is assigned to make sure they understand the nature of their assignment.

3.2. International Students

There are some special requirements for international students to ensure that your visa status remains compliant. A few key issues/reminders:

- Ensure that you are enrolled in 9 credit-hours each semester
  - Courses taken in 'hearer' status do not count toward this total
  - Undergraduate courses taken for any reason do not count toward this total
- If you change your major or degree level (i.e. from MS to PhD), make sure to apply for a new I-20/DS-2019 as soon as possible
- Do not work for an off-campus employer for any reason without receiving special authorization
- See your International Advisor for help with various topics
  - Passport/visa renewal
  - Change of status
  - Adding dependents to immigration status
  - Employment information
  - Driver's license / Social Security Number
  - Travel

3.3. Area of Specialization and Faculty Advisor

Students are expected to exercise initiative in choosing a research area and advisor. This is one of the most important decisions they can make related to their future career. It is our policy to provide students with as much information as possible. Students are encouraged to visit multiple faculty, unless a faculty advisor has been approved prior to arrival. A faculty advisor should be selected as soon as possible, but no later than the last week of a student's first semester of classes.

Responsibilities of the Advisor

Some responsibilities of our academic advisors include:

- Endeavor to know his/her advisee well enough to be able to write a cogent letter of reference if requested to do so.
- Exhibit good listening and questioning skills in order to identify academic and/or personal problems which may affect academic performance.
- Discuss academic/educational goals and career options and interests of the student being advised, to assist students in selecting appropriate courses.

- Assess the student's ability to successfully complete the proposed academic load and offer suggestions for modification when appropriate.
- Be aware of campus facilities and resources which are in place to assist students and be prepared to refer students to these programs when appropriate. Offer to assist in making appointments and follow ups as appropriate.
- Be generally aware of campus rules and procedures relating to academic matters. Examples include, but are not limited to, add/drop procedures and deadlines, change of grading option and probationary rules.

Responsibilities of the Advisee

- Attend all scheduled advising appointments with your academic advisor.
- Be prepared; write down questions and concerns that you may have.
- Check your e-mail on a regular basis and respond to e-mails sent to you by your advisor.
- See your advisor as soon as you begin to experience academic problems.
- Bring a proposed schedule with you to pre-registration appointments; this may not be a final schedule, but provides you and the advisor with a starting point.

For MS with thesis students, identification of a research topic is dependent on the research opportunities that are available at the time, as well as the manner in which the student is supported. Self-supported students or fellowship recipients have more freedom to select a topic but must select one consistent with the faculty in the Nuclear Engineering Program. Students should obtain suggestions from faculty members and try to find a match between faculty interests and their own. Students requiring support in the form of assistantships are constrained to research areas for which current grants or contracts exist. In this case, students must be willing to work on the area of choice and perform well, so that the goals of the contract or grant funding their research can be satisfied.

3.4. ASSISTANTSHIPS AND FELLOWSHIPS

The Nuclear Engineering Program must make efficient use of limited funding for graduate assistantships and fellowships to assist faculty in teaching and research. These appointments are offered and continue on a competitive basis. Renewal of graduate assistantships requires satisfactory performance and appropriate progress to degree completion. Graduate Assistant performance is evaluated on

- Overall academic performance – maintaining a B average, and B or better in all Nuclear Engineering courses
- End-of-semester reviews provided by faculty who have been assigned teaching assistants
- End-of-semester reviews provided by faculty supervising research assistants or fellows
- The grade assigned for research by their advisor – unsatisfactory grades are considered very seriously

Every effort will be made to maintain funding for students in good standing, provided that funding remains available. In case funding is unavailable, every effort will be made to give students advance notice of a pending change in support. Unsatisfactory performance in any of these areas may result in reduction, termination, or non-renewal of the graduate appointment. Students will be notified of such a decision in writing. For MS students, the typical period of support is 4 semesters (not including summer semesters). For PhD students, the typical period of support is 8 semesters (not including summer semesters).

It is very important for students to realize that employment as a graduate research assistant requires that they spend the assigned time – 20 hours/week for a 50% FTE appointment or 10 hours/week for a 25% FTE appointment – on the assigned research project and perform as expected by the faculty supervisor. Both the student and faculty supervisor have a responsibility to deliver appropriate, on-time results to the research sponsor. It is extremely important that students maintain a good working relationship with their advisor/supervisor. That relationship is one of the most important factors for successfully completing a graduate degree program.

4. MS Degree Programs

4.1. Plan of Study

The MS program is determined by the student in consultation with their advisor. However all students are expected to have a basic knowledge of Nuclear Engineering. Therefore students with undergraduate degrees in other disciplines should expect to complete sufficient undergraduate and graduate courses to master the fundamentals of Nuclear Engineering. These are listed as the Core Courses in the tables below. Students are also expected to complete sufficient courses and/or research to develop expertise in one area of concentration. A thesis option exists for students interested in graduate research, while a non-thesis option is targeted for students with significant prior experience in industry or research.

Recommended Courses for a MS in Nuclear Engineering (Thesis Option)

Core Courses[1]	
NUC ENG 3205: Fundamentals of Nuclear Engineering	3 Credits
NUC ENG 5203: Reactor Physics I	3 Credits
NUC ENG 5241: Nuclear Materials I	3 Credits
NUC ENG 5257: Introduction to Nuclear Thermal Hydraulics	3 Credits
NUC ENG 5312: Radiation Laboratory I	3 Credits
NUC ENG 6010: Graduate Seminar[2]	1 Credit
Math or Computer Science Elective	
Graduate level mathematics, computer science, or numerical methods	3 Credits
Engineering Electives	
5000 Engineering Elective[3,4]	3 Credits
6000 Engineering Elective[3]	3 Credits
NUC ENG 6099: Graduate Research	6 Credits
Total:	**31 Credits**

[1] Students with an undergraduate degree in Nuclear Engineering may have completed some or all of these requirements as part of their previous coursework. In that case, these Core Courses will be additional Engineering Electives at the 5000 level or above.

[2] Students are expected to register for two semesters, at 0.5 credits each semester.

[3] Engineering electives can be from any department on campus. These are negotiated with the student's faculty advisor and should be focused on their area of concentration.

[4] Up to 3 credits of 5000 level Engineering Electives can be replaced by additional credit in 6099: Graduate Research.

Recommended Courses for a MS in Nuclear Engineering (Non-Thesis Option)

Core Courses[1]	
NUC ENG 3205: Fundamentals of Nuclear Engineering	3 Credits
NUC ENG 5203: Reactor Physics I	3 Credits
NUC ENG 5241: Nuclear Materials I	3 Credits
NUC ENG 5257: Introduction to Nuclear Thermal Hydraulics	3 Credits
NUC ENG 5312: Radiation Laboratory I	3 Credits
NUC ENG 6010: Graduate Seminar[2]	1 Credit
Math or Computer Science Elective	
Graduate level mathematics, computer science, or numerical methods	3 Credits
Engineering Electives	
5000 Engineering Electives[3]	6 Credits
6000 Engineering Elective[3]	6 Credits
Total:	**31 Credits**

[1] Students with an undergraduate degree in Nuclear Engineering may have completed some or all of these courses as part of their previous coursework. In that case, these Core Courses will instead be additional Engineering Electives at the 5000 level or above.

[2] Students are expected to register for two semesters, at 0.5 credits each semester.

[3] Engineering electives can be from any department on campus. These are negotiated with the student's faculty advisor and should be focused on their area of concentration.

Sample Concentration Areas:

Nuclear Policy & Nonproliferation

Contribute to keeping the nation and our nuclear material safe. Advocate for science-based policy surrounding nuclear energy and nuclear materials and promote peaceful uses for nuclear technology. Contribute to technologies and policies that will reduce the threat of nuclear conflict.

Suggested electives:

NUC ENG 5507: Nuclear Policy
NUC ENG 5509: Nuclear Nonproliferation
NUC ENG 5577: Advanced Nuclear Forensics and Spectroscopy
NUC ENG 6331: Radiation Shielding

Nuclear Power Engineering

For those considering a career in nuclear energy at a nuclear utility, vendor, or startup. This can include nuclear fuel design, developing improvements for nuclear power plants, or cutting-edge research on new nuclear technologies.

Suggested electives:

NUC ENG 5259: Licensing of Nuclear Power Plants
NUC ENG 5253: Monte Carlo Approach to Reactor Analysis
ECONOMICS 5540: Advanced Energy Economics
NUC ENG 6203: Advanced Reactor Physics

Nuclear Reactor Safety

Develop safety improvements in nuclear power plants. Understand and provide science-based contributions to improve the regulations surrounding nuclear energy.

Suggested electives:

NUC ENG 5281: Probabilistic Risk Assessment
NUC ENG 5347: Radiological Engineering
MECH ENG 5139: Computational Fluid Dynamics
NUC ENG 6257: Advanced Nuclear Thermal Hydraulics

Health Physics

Understand radiation hazards and how to prevent or control them. Help make hospitals, regulators, or industries where radiation is used or encountered safe for staff and customers. Manage environmental procedures for institutions using radiation-based technologies in a wide range of applications.

Suggested electives:

NUC ENG 5263: Applied Health Physics
NUC ENG 5281: Probabilistic Risk Assessment
NUC ENG 5347: Radiological Engineering
NUC ENG 6331: Radiation Shielding

List of Elective Courses:

The complete list of graduate courses offered in NERS can be found in the graduate catalog at https://catalog.mst.edu/graduate/graduatedegreeprograms/nuclearengineering/#courseinventory.

A full list of course availability and timing can be found at https://cec.mst.edu/academics/course-availability/

4.2. GRADUATE CERTIFICATES

The nuclear engineering program offers a graduate certificate program to professionals and students who desire to undergo formal instruction in nuclear nonproliferation. The topics in comprising the certificate program are selected from courses available to graduate students in the nuclear engineering program at Missouri University of Science and Technology. All courses are available both in traditional on-campus delivery and online format. The certificate program deployment strategy allows all enrollees to pace their study in manner consistent with the individual's plans. The Graduate Certificate in Nuclear Nonproliferation is open to all persons holding a B.S., M.S., or Ph.D. degree in Engineering, Science, and/or Mathematics as well as related B.A. or M.A. degrees, or are currently accepted into a graduate degree program at Missouri S&T.

The certificate program requires 4 courses equivalent to 12 credit hours. There are 8 course available to the certificate program, 1 of which is required for the completion of the graduate certificate in nuclear nonproliferation. Program enrollees may select any 3 of the remaining 7 courses towards the completion of the graduate certificate. Enrollees may take 1 or 2 classes each semester so that the certificate program may be completed within 1 to 2 years.

Required Course:

- NUC ENG 5509: Nuclear Nonproliferation

Elective Courses:

- NUC ENG 5207: Nuclear Fuel Cycle
- NUC ENG 5281: Introduction to Probabilistic Risk Assessment
- NUC ENG 5312: Nuclear Radiation Measurements and Spectroscopy
- NUC ENG 5347: Radiological Engineering
- NUC ENG 5577: Advanced Nuclear Forensics and Radiochemistry
- NUC ENG 5507: Nuclear Policy
- NUC ENG 6331: Radiation Shielding

4.3. REGISTRATION

All students seeking a MS degree must file a Form 1, their plan of study (http://grad.mst.edu/currentstudents/forms/). The MS plan of study must represent a coherent, integrated program of formal study. The plan of study may include at most three credits of 3000 level courses. Students are encouraged to take at least six credits of courses outside of their program. At least one credit of graduate seminar, NUC ENG 5010, is required as two separate 0.5 credit instances. For a thesis option, at least 6 credits of graduate research are required. Students are limited to a maximum of four credit hours in courses numbered 5000, 5010, 6000, and/or 6010 on their program of study. Non-thesis students are not allowed to include graduate research on a program of study. A maximum of nine credit-hours of graduate level courses taken elsewhere as

a graduate student can be transferred to the MS plan of study, provided that the courses correspond to at least a 5000 level course at S&T.

The plan of study also requires that three advisory committee members be selected. The advisory committee consists of faculty with specializations related to the student's research topic, who can provide useful input for and constructive criticisms of their research, and who can fulfill the examination role in the final examination. Recommended committee members should be discussed with the student's advisor. It is possible for faculty from other universities or qualified individuals from national laboratories or other organizations to be included in the committee, if appropriate. Students should periodically discuss their research with their committee members.

Students are strongly encouraged to complete the Form 1 during the first semester of their graduate program, however are required to do so within six weeks of the beginning of the semester in which the student takes his or her fifteenth graduate credit hour. Students who fail to comply with this deadline will have a registration hold placed on their account.

Each student should bring a proposed schedule to their advising appointment. After discussing the proposed schedule, they should complete an Advising Agreement form. The selected courses should conform to their official plan of study and, for international students, any visa requirements or requirements of supporting agencies that may apply.

Students should register for research (NUC ENG 6099) when they are conducting research under faculty direction, or when they require university facilities for research. Graduate students must be registered for a minimum of 9 hours to remain full-time, unless they are registering for examination or degree only.

During the semester in which a student expects to receive their degree, they should check with the Office of Graduate Studies to ensure that all requirements are successfully completed. Ensuring that all requirements are met is the student's responsibility. Should the student not meet all requirements, they will not graduate that semester and will need to register for the next semester.

Registration for off-campus research is possible. Off-campus research must be supervised by a member of the Missouri S&T faculty, and must have the prior written approval of the student's graduate advisor, department chair, and the dean of graduate studies (the application to do non-resident research, as well as all other relevant forms, is available online at http://grad.mst.edu/currentstudents/forms/). Care must be taken to ensure that an off-campus research endeavor will result in educational experiences equivalent or superior to those that a student might expect to have at Missouri S&T.

4.4. GRADUATION

MS With Thesis Milestones:

1. The student will complete academic requirements.
2. The student will check with the registrar to make application for graduation within four weeks of the beginning of the student's final semester, or within two weeks of the beginning of the summer session. The student must apply for graduation though their Joe'SS account.

3. The student will arrange a date, time, and place for the oral examination, or thesis defense, and forward this information to the office of graduate studies electronically. The student must be enrolled at the time of oral examination.
4. The student will distribute copies of the thesis to all members of the examining committee at least seven working days before the oral examination.
5. The chair of the examining committee will report the action of the committee to the office of graduate studies by submitting Form 2, accompanied by a copy of the committee approved thesis for format check.
6. The advisory committee completes the Outcomes Rubric for the Final Examination. The result of the evaluation is intended only for program evaluation and will not be reported (except as aggregate data) nor affect the student's ability to graduate.
7. Once the format check is complete the office of graduate studies will direct the student to submit the final copy of the thesis electronically to the ETD website, provided the student has fulfilled all academic requirements and has paid all enrollment or examination fees.
8. Upon departmental request, the student may present one copy of the approved thesis to the department chair and one to the thesis advisor, and may retain one copy for his or her personal records.
9. The Board of Curators will, upon the recommendation of the graduate faculty, grant the student the master of science degree when all degree requirements are met and all enrollment or examination fees have been paid.

Masters thesis preparation:

The findings and results of research undertaken by the candidate for a master's degree must be presented in a written thesis. A manual entitled "Specifications for Thesis and Dissertations" is available at http://grad.mst.edu/currentstudents/thesisdissertationinformation/formatting/. This manual outlines the specific requirements for the thesis. Effective June 1, 2013, the final copy of the thesis must be submitted electronically unless an indefinite hold is being placed on the thesis.

The MS thesis should document research results in a clear, concise fashion, and it should be prepared while in residence. Students should consult with their advisor to determine appropriate scope and organization for their thesis.

Final examination:

When the thesis is completed, the candidate distributes a copy to each member of his or her advisory committee and arranges a time and place for the oral examination, or defense, of the thesis. These oral examinations are normally scheduled when the university is officially in session, and the candidate must be enrolled at the time of the examination. An on-campus candidate for a graduate degree may enroll during the intersession for the final examination only (course 5040) for no hours of credit and pay the examination fee. Each committee member should be allowed to examine the thesis for at least seven working days before the oral defense. While questions typically address the material presented in the thesis, however in some cases the defense may be

comprehensive in character and include questions on related fundamentals. The candidate should be able to demonstrate an acceptable level of knowledge of a professional area, as defined by his or her degree program.

For the candidate to pass the examination, every member of the examining committee must vote affirmatively. If any member votes not to pass the candidate, the dean of graduate studies shall appoint a new examining committee on which the dissenting member may be replaced, and the new committee will administer a second examination. A student who fails a second time will no longer be eligible to receive a graduate degree from that program. However, the student is still eligible to pursue a graduate degree from any other graduate degree program willing to accept him or her.

Immediately following the thesis defense, the chair of the examining committee will report the action of the committee (on Form 2) first to the department chair and then to the dean of graduate studies. Approval of Form 2 signifies that the members of the committee examined the thesis closely for both scientific content and format, and determined that it meets the requirements for a master's degree and is worthy of acceptance by the graduate faculty of Missouri S&T.

At the close of a successful thesis defense, the members of the examining committee will sign Form 2 to signify that they have read and approved the thesis. If the committee indicates that corrections must be made to the thesis, the student must make such corrections and then seek approval of the revised thesis from the committee members and obtain the necessary signatures. The final approved copy of the thesis is then taken to the office of graduate studies, where it is carefully checked to ensure that the document is properly formatted according to the specifications available online. After the office of graduate studies approves the document, it is submitted electronically (unless there is an indefinite hold) to the electronic thesis/dissertation (ETD) website. Upon a departmental request, the student may present one copy of the approved thesis to the department chair and one to the thesis advisor, and may choose to retain one copy for his or her personal records.

MS Without Thesis Milestones:

1. The student will consult with the graduate advisor about course scheduling and register for classes.
2. The student will select an advisor, and complete Form 1 (typed original) within six weeks of the beginning of the semester in which the student takes his or her fifteenth graduate credit hour. Students who fail to comply with this deadline will have a registration hold placed on their account.
3. The student will complete academic requirements.
4. The student will check with the registrar to make application for graduation within four weeks of the beginning of the student's final semester, or within two weeks of the beginning of the summer session. The student must apply for graduation through their Joe'SS account.

5. The student will work with the graduate advisor and the department chair to complete and submit Form 1-B, which identifies potential members of the student's examining committee.
6. The dean of graduate studies will formally appoint the student's examining committee.
7. The student will submit a portfolio of their academic work for their examining committee to evaluate. The portfolio may include graded assignments, reports, laboratory reports, presentations, or any other material the student deems relevant. The student's examining committee will complete the Outcomes Rubric. The result of the evaluation is intended only for program evaluation and will not be reported (except as aggregate data) nor affect the student's ability to graduate. An on-campus candidate for a graduate degree may enroll during the intersession for the final examination only (course 5040) for no hours of credit and pay the examination fee.
8. The chair of the examining committee will report the action of the committee to the office of graduate studies, using Form 3.
9. The Board of Curators will, upon the recommendation of the graduate faculty, grant the student the master of science degree when all degree requirements are met and all enrollment or examination fees have been paid.

5. PhD Degree Programs

5.1. Plan of Study

The Doctor of Philosophy (PhD) program is open to students who have successfully completed their MS program or have enrolled in a direct PhD program. Typically a minimum of 5 semesters (not including summer sessions) is required to complete the program for students arriving with a MS degree, and a minimum of 7 semesters for students starting a direct PhD program. A student is considered a doctoral-level student only after he or she satisfactorily completes thirty credit hours of graduate study. Students must then pass a Ph.D. qualifying examination and submit a plan of study before they can be formally considered candidates for the doctoral degree.

The proposed Ph.D. program of study, Form 5, must be submitted by the end of the semester in which the student passes his or her qualifying examination, but no later than six weeks into the fifth semester of enrollment. The subjects of study for the Ph.D. may be chosen from one or more departments, as determined by the advisory committee, but shall constitute a definite plan of training for research or scholarly investigation in some particular field. Students must designate a major field of study, and are encouraged to select one minor field of study consisting of at least twelve credit hours of work outside their major area of study. Up to 30 credits of coursework from a MS degree can be applied to the PhD plan of study.

Recommended Courses for a Doctorate in Nuclear Engineering

Core Courses[1]	
NUC ENG 3205: Fundamentals of Nuclear Engineering	3 Credits
NUC ENG 5203: Reactor Physics I	3 Credits
NUC ENG 5241: Nuclear Materials I	3 Credits
NUC ENG 5257: Introduction to Nuclear Thermal Hydraulics	3 Credits
NUC ENG 5312: Radiation Laboratory I	3 Credits
NUC ENG 6010: Graduate Seminar[2]	3 Credit
Math or Computer Science Elective	
Graduate level mathematics, computer science, or numerical methods	6 Credits
Engineering Electives	
5000 Engineering Elective[3,4]	12 Credits
6000 Engineering Elective[3]	9 Credits
NUC ENG 6099: Graduate Research	24 Credits
Total:	**72 Credits**

[1] Students with an undergraduate degree in Nuclear Engineering may have completed some or all of these requirements as part of their previous coursework. In that case, these Core Courses will be additional Engineering Electives at the 5000 level or above.

[2] Students are expected to register for six semesters, at 0.5 credits each semester.

[3] Engineering electives can be from any department on campus. These are negotiated with the student's faculty advisor and should be focused on their area of concentration.

[4] Up to 12 credits of 5000 level Engineering Electives can be replaced by additional credit in 6099: Graduate Research.

The doctoral program will include at least 24 credit hours of graduate research. Students are encouraged to enroll in fifteen credit hours of 6000-level lecture courses during the span of their doctoral program, but are required to include at least 9 credit hours. Students are also encouraged to enroll in at least six credits of advanced mathematics or computer science courses. Correspondence and extension courses do not form part of the program for the Ph.D. degree, except as they constitute a part of a master's program. Correspondence and extension courses beyond those allowed for a master's degree may not be applied to a doctoral degree program. Distance sections of Missouri S&T approved courses may be applied to the doctoral degree program.

Before submitting the Form 5, the doctoral candidate will consult with an advisor of his or her choice to select an advisory committee. The committee will consist of at least five members, and the chair of the committee and at least three other members should belong to the graduate faculty. The advisory committee must include at least one member from outside the candidate's major department. One member of the committee should also be designated to represent the department most closely associated with any minor field of study elected by the student. The names of the proposed members of the advisory committee will be listed on Form 5 and sent by the student's department chair to the office of graduate studies for formal appointment. Additional members and replacement members may be appointed using Form 5-A.

Key milestones in the PhD program:

1. The student initiates his or her candidacy for the doctoral degree by meeting both of the following requirements
    a) The student passes a qualifying examination administered by the department in which the student intends to become a doctoral degree candidate.
    b) The student satisfactorily completes the first thirty hours of graduate study in his or her designated program. Credit earned toward a previous MS degree can be included in this requirement. Candidacy must be established prior to the beginning of the fifth semester (not counting summer sessions) of enrollment as a graduate student in a doctoral program. Graduate Forms 4 and 5 must be completed and submitted no later than six weeks into the student's fifth semester of enrollment.
2. The candidate consults with his or her academic advisor about possible members of the advisory committee. The advisor, with the approval of the department chair, submits Form 5 to the dean of graduate studies, requesting formal appointment of the advisory committee.
3. The candidate solicits the aid of his or her committee members in preparing an outline of courses and research, and, with the help of his or her advisor, completes and submits Form 5 to the office of graduate studies.
4. The candidate takes the Ph.D. comprehensive examination, and the advisory committee reports the results of the examination to the dean of graduate studies by completing and submitting Form 6B. Members of the advisory committee must also complete the Learning Objectives rubric. After the candidate passes the comprehensive examination, he or she must maintain continuous enrollment until the degree is completed, or the candidacy is cancelled.
5. The candidate checks with the registrar to make application for graduation within four weeks of the beginning of his or her final semester, or within two weeks of the beginning of the summer session. The student must apply for graduation through their Joe'SS account.
6. The candidate, in consultation with his or her advisor, selects the date, time, and place of the final examination – at least 12 weeks following the comprehensive examination – and informs the office of graduate studies electronically, so that the examination can be publicized at least one week in advance. *Note: The candidate must be enrolled at the time of his or her examination. An on-campus candidate for a graduate degree may enroll during the intersession for the final examination only (course 6040) for no hours of credit and pay the examination fee.*
7. The candidate takes the Ph.D. final exam, and the advisory committee reports the results of the examination to the office of graduate studies by completing and submitting Form

7, accompanied by a committee approved copy of the dissertation for format check. The advisory committee will also complete the Learning Objectives rubrics.

8. Once the format check is complete the office of graduate studies will direct the student to submit the final copy of the dissertation electronically to the ETD website , providing the candidate has fulfilled all academic requirements and has paid all enrollment or examination fees and submitted a certificate of completion of the "Survey of Earned Doctorates" (https://sed-ncses.org/). (If an indefinite hold is placed on the dissertation the office of graduate studies will inform the student of submission requirements.)
9. Upon department request, the candidate may present one copy of the approved dissertation to the department chair and one to the advisor, and may retain one copy for his or her personal records.
10. The Board of Curators, upon the recommendation of the graduate faculty, grants the candidate the doctor of philosophy degree.

Many of the requirements (i.e. selecting and advisor, or dissertation requirements) are similar to those for MS degrees and so are not detailed further in this section. Students should refer to Section 4 of this handbook for such information.

5.2. RESIDENCY

Residency at Missouri S&T is defined as sustained intellectual interactions among the student and the academic community. The candidate for a Ph.D. degree will normally complete three years of residency, which is the equivalent of completing six academic semesters while enrolled as an on-campus student at Missouri S&T. Students holding a master's degree are automatically credited with two semesters of residency.

Students unable to meet the residency requirement given above, such as distance students, can meet this requirement through an alternative route. In consultation with their advisor, the student can utilize other experiences towards meeting the residency requirements. Such experiences include regular contact with the student's advisor, committee members, and other graduate students, participation in a seminar series, etc. Other experiences that would count towards earning residency are listed in a supplemental document available from the office of the dean of graduate studies. It is the responsibility of the student's faculty advisor to document suitable residency experiences each semester.

5.3. QUALIFYING EXAMINATION

All students wishing to pursue a doctoral degree must pass the qualifying examination no later than the fifth semester of enrollment as a graduate student in the doctoral program. This examination may be taken after the student has been accepted to Missouri S&T, but prior to the student's initial enrollment, if the student desires. The department chair will report the results of the qualifying examination to the office of graduate studies using Form 4.

The objective of the PhD Qualifying Examination is to determine as early as possible whether a student has sufficient capability and background to conduct the original, independent research that is required in the PhD program. The qualifying examination in NERS includes two (2) segments: a Pre-Qualification Assessment and Research Readiness Assessment.

The Pre-Qualification Assessment is to prepare NERS graduate students academically for the discipline and test their preparedness. The assessment is rooted in nuclear engineering courses, especially those relevant to the focus area of the graduate student. For this assessment, the graduate student must have earned a B or better in five (5) of the following courses, in a combination consisting of at least one (1) NUC ENG 6XXX course:

- NUC ENG 5203: Reactor Physics
- NUC ENG 5207: Nuclear Fuel Cycle
- NUC ENG 5257: Introduction to Nuclear Thermal Hydraulics
- NUC ENG 5241: Nuclear Materials,
- NUC ENG 5312: Radiation Measurements and Spectroscopy
- NUC ENG 5347: Radiological Engineering
- NUC ENG 5363: Applied Health Physics
- NUC ENG 5509: Nuclear Nonproliferation
- NUC ENG 5577: Nuclear Forensics and Radio Chem
- NUC ENG 6001: Special Topics
- NUC ENG 6203: Advanced Reactor Physics
- NUC ENG 6241: Effects of Radiation on Solids
- NUC ENG 6257: Advanced Nuclear Thermal Hydraulics
- NUC ENG 6331: Radiation Shielding

Where any of these courses is not offered, a substitution may be made with a 5XXX or 6XXX course of similar content or subject matter. A student who has earned a MS degree in nuclear engineering from any institution may apply courses taken for the MS degree towards the Pre-Qualification Assessment as long as the courses being applied are comparable to the specified NERS courses. Students are highly encouraged to consult with their advisory committee to select the five (5) courses to be applied towards the Pre-Qualification Assessment.

A student is eligible to take the Research Readiness Assessment only after satisfactory completion of the Pre-Qualification Assessment. The Research Readiness Assessment constitutes the core of the Qualifying Examination. Each student will be allowed two (2) attempts to pass the Research Readiness Assessment, separated by at least two (2) semesters. The Research Readiness Assessment will be administered by the Qualifying Examination Committee, consisting of three Nuclear Engineering faculty members appointed by the Program Chair.

- One member will be appointed chair of the Committee.
- The committee chair may request input from faculty who are not members of the Committee.
- Alternate members may be appointed by the committee. Such members will serve as alternate for committee members with conflict of interest.

The Research Readiness Assessment will be announced approximately four weeks prior to the scheduled exam date. Those interested in participating should contact the chair of the committee within two weeks after the announcement. If a student subsequently withdraws from the exam, the exam will be considered a failure.

The Research Readiness Assessment consists of a written proposal or critical review of the student's research subject matter followed by a presentation. A written proposal must clearly state the research objective, provide the background to the research, do a deep dive into the current state of the art in the research, and identify direction(s) in which the research can proceed. A critical review may not have a stated research objective, but in addition to the other contents identified for a proposal, it should provide insightful review of the current research endeavors in the focus area. The proposal or critical review must be submitted to the chair of the Qualifying Examination Committee two (2) weeks prior to the presentation date or not later than a date specified by the Qualifying Examination Committee.

The passing requirement for the Research Readiness Assessment will be determined by the Committee based on a research readiness assessment rubric. The assessment rubric will be used to evaluate the following:

- *Foundational knowledge*: level of understanding of core principles and advanced topics relevant to the research.
- *Research approach*: level of proficiency in research methodologies, experimental design, data analysis, and use of advanced tools/software.
- *Critical thinking and problem-solving skills*: competency in identifying, analyzing, and solving complex research problems independently.
- *Communication skills*: Competency in communicating research findings clearly and effectively in both written and oral formats to a specific audience.
- *Professionalism and ethics*: level of understanding of research ethics and professionalism, adherence to ethical guidelines, and maintenance of integrity.

Each assessment criterion is evaluated as Exceeds Expectations, Meets Expectations, Approaching Expectations, or Below Expectations. A passing outcome means the student meets expectation in the overall assessment. Students who do not pass the Research Readiness Assessment on their first attempt will be provided with the opportunity to take that Assessment again the following year. Students will be notified of the results of their examination by the committee chair in writing, no later than six weeks following the exam. Students who do not pass the Research Readiness Assessment after their second attempt will be required to exit the PhD program. Such students may transfer their course credits towards MS or DE degree programs.

5.4. COMPREHENSIVE EXAMINATION

After the student has completed at least 50% of the coursework required for a doctoral degree, as listed on the student's approved program of study (Forms 5 and 5-A), a student may schedule their comprehensive exam. The comprehensive exam for Nuclear Engineering consists of an oral presentation to the advisory committee on

- The current status of the student's dissertation research
- The ongoing work the student plans to complete prior to their final examination
- Published and expected publications resulting from their research

The comprehensive exam should be considered a proposal for the dissertation, with the advisory committee in the role of reviewer. Therefore the advisory committee may recommend changes to methods, additional tests or simulations, or similar steps to improve the strength of the dissertation research. The advisory committee will then evaluate the candidate's proposal on

- The quality and originality of the candidate's proposed research, including methods and any preliminary results
- The candidate's knowledge of relevant historical and state-of-the-art research related to the topic
- The quality of the candidate's presentation and discussion of their proposed research
- The publication potential of the candidate's proposed work

The results of the comprehensive examination will be sent to the dean of graduate studies, using Form 6B. A student will be considered to have passed the examination if all, or all but one, of the advisory committee members vote that the student pass.

If the student fails the comprehensive examination, the advisory committee will recommend additional work or other remedial measures to the candidate. A second comprehensive examination may be scheduled no sooner than twelve weeks after the student's first attempt. A student who fails the examination a second time will no longer be eligible to receive a graduate degree from that program. However, the student is still eligible to pursue a graduate degree from any other graduate degree program willing to accept him or her.

5.5. FINAL EXAMINATION

The final examination is an oral defense of the dissertation and may be attended by any interested person. Attendees may question the candidate with the permission of the chair of the advisory committee. The dean of graduate studies will authorize the student's advisory committee to administer the final examination, which may be scheduled no sooner than twelve weeks after the completion of the comprehensive examination. Notice of the final examination, along with the dissertation abstract, shall be publicized by the office of graduate studies at least one week prior to the examination. The advisory committee shall closely examine the dissertation for both scientific content and format, in order to determine that it meets the requirements for a doctoral degree and is worthy of acceptance by the graduate faculty of Missouri S&T. A report of the examination results will be sent to the office of graduate studies using Form 7. The advisory committee will also complete the relevant GLO evaluation forms.

The candidate's final examination will be evaluated on

- The quality and originality of the candidate's research
- The candidate's knowledge of relevant historical and state-of-the-art research
- The quality of the candidate's presentation and discussion of their research

- The publication potential of the candidate's proposed work. Typically PhD candidates are expected to have 2-3 journal publications at least under review in appropriate scientific journals or conferences.

A candidate will be considered to have passed the final examination if all, or all but one, of the advisory committee members vote that the student pass. If the student fails the final examination, the committee will recommend additional work or other remedial measures to be taken before another examination is scheduled. At the close of a successful final examination, the members of the examining committee will sign the Form 7 to signify that they have read and approved the dissertation. If the committee indicates that corrections must be made, the student must make such corrections and then seek approval of the revised dissertation from the committee members and obtain the necessary signatures. The final approved copy of the dissertation is then taken to the office of graduate studies, where it is carefully checked to ensure that the document is properly formatted according to the specifications available online. After the office of graduate studies approves the document, it is submitted electronically (unless there is an indefinite hold) to the electronic thesis/dissertation (ETD) website. Upon departmental request, the student may present one copy of the approved dissertation to the department chair and one to the dissertation advisor, and may choose to retain one copy for his or her personal records.

6. STUDENT ORGANIZATIONS

Reactor Operator Licensing Program

Our students have the opportunity to become licensed Reactor Operators (ROs). Students will work with reactor staff, study relevant Nuclear Regulatory Commission (NRC) regulations, learn the fundamentals of day-to-day operations, spend time in the control room, and take the NRC reactor operator's exam. Some students may also have the chance to complete Senior Reactor Operator (SRO) licensing.

This license does not 'travel', so students seeking employment as ROs at other reactors would have to re-license. However this program provides valuable learning, experience, and insight into the process. Students who are interested in the program should contact Ethan Taber (etaber@mst.edu)

American Nuclear Society

The American Nuclear Society (ANS) is a not-for-profit, international, scientific and educational organization. It was established by a group of individuals who recognized the need to unify the professional activities within the various fields of nuclear science and technology. December 11, 1954, marks the Society's historic beginning at the National Academy of Sciences in Washington, D.C. ANS has since developed a diverse membership composed of approximately 11,000 engineers, scientists, administrators, and educators representing 1,600 plus corporations, educational institutions, and government agencies. It is governed by four officers and a board of directors elected by the membership.

Vision: ANS will be the recognized, credible advocate for advancing and promoting nuclear science and technology.

Mission: ANS provides its members with opportunities for professional development. It also serves the nuclear community by creating a forum for sharing information and advancements in technology, and by engaging the public and policymakers through communication outreach. Mission components can be found in the ANS strategic plan.

Purpose: The core purpose of ANS is to promote the awareness and understanding with regard to the application of nuclear science and technology.

The ANS Student Chapter at Missouri S&T is a student-led professional organization. The mission of the Missouri S&T American Nuclear Society is to promote understanding in, and advancement of, the sciences pertaining to the atomic nucleus in our community, especially those for peaceful applications. The chapter was founded in 1967. The organization creates opportunities to experience Nuclear Engineering outside of the class room and open doors to professional relationships and networking by providing the opportunity to travel to ANS conferences, national laboratories, and so on.

Women In Nuclear

U.S. Women in Nuclear (U.S. WIN) is the premier network of over 8,000 women and men who work in nuclear- and radiation-related fields around the country. The U.S. WIN organization was established in May 1999 with the following strategic objectives:

- To support an environment in nuclear energy and nuclear technologies in which women and men are able to succeed
- To provide a network through which the women and men in these fields can further their professional development
- To provide an organized association through which the public is informed about nuclear energy and nuclear technologies.

U.S. WIN members participate in networking, professional development and outreach activities through local chapters, regional organizations, and the national organization. Local chapters are organized based on company, university/college, or geographic region. In addition, U.S. WIN is an affiliate of the Women in Nuclear Global organization (WiN Global). The WiN-Global organization is made up of thousands of members in more than 100 countries.

Membership is open to both men and women at Missouri S&T. We strive to help provide a network for members to further their professional development, inform the public about nuclear energy and technology, and encourage women and diversity to participate in the nuclear, engineering, and energy fields.

Nuclear Science Design Team

Missouri S&T design team experience prepares students for success in whatever endeavor they may choose. These student-led teams learn the organizational problem-solving process essential for the successful development of a market-ready product. Business, marketing, logistics, communications and teamwork skills that design teams incorporate in their day-to-day operations mirror the global design process used in industry world-wide. Design team members network with industry professionals and students from competing schools alike, forming personal and professional relationships that can lead to rewarding careers.

S&T design team veterans "know how to think on their feet, don't mind getting their hands dirty, and are ready to contribute on their first day at work" say many firms who hire our team members, and why so many businesses aggressively recruit S&T students with design team experience.

The Nuclear Science Design Team (NSDT) develops original ideas or concepts related to nuclear science and technology. Final designs or papers are submitted to national competitions, including the yearly ANS student design competition. The purpose of the organization is:

1. Research, design, and build nuclear devices
2. Participate in American Nuclear Society competitions
3. Promote technological advancement, particularly in nuclear fields
4. Expand members' knowledge of classroom concepts
5. Increase awareness of environmental protection and health safety throughout all aspects of developing NSDT next project
6. Develop skills that will prepare members for leadership roles in industry
7. Promote cooperation between multiple scientific and engineering disciplines
8. Promote the University through ANS competitions and public outreach programs

Past projects include construction of an Inertial Electrostatic Confinement (IEC) fusor. The team is always looking for new members. All students are welcome. Any major and no experience required.